

**Estimation of the 1994 Chilko River and
Chilko Lake System Sockeye Salmon
(*Oncorhynchus nerka*) Escapement**

N.D. Schubert and B.P. Fanos

Fisheries and Oceans Canada
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ABSTRACT

Schubert, N.D., and B.P. Fanos. 1997. Estimation of the 1994 Chilko River and Chilko Lake sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2428: 54 p.

In 1986, the Department of Fisheries and Oceans (DFO) assumed responsibility from the International Pacific Salmon Fisheries Commission (IPSF) for the estimation of the escapement of Fraser River sockeye salmon (*Oncorhynchus nerka*) stocks. DFO adopted the IPSF's two-tiered system whereby large escapements (25,000+) were estimated using enumeration fences or mark-recapture studies, and small escapements (less than 25,000) were estimated using visual techniques.

The Chilko River system supports four sockeye salmon stocks which spawn in the Chilko and Taseko rivers and the north and south ends of Chilko Lake; the escapement of these stocks exceeded 25,000 every year since 1943. The 1994 study area included the populations in the Chilko River and the north and south ends of Chilko Lake. Sockeye were captured while migrating through the Chilko River at a site near the lower limit of spawning; 3,638 were released with disk tags. The spawning grounds were surveyed through the period of spawning and die-off; 102,030 carcasses were recovered, of which 819 had disk tags. The 1994 study area escapement was estimated, using the pooled Petersen estimator, at 187,684 adult males, 261,131 adult females and 1,477 jacks (ages 4₃ and 3₂ males or females).

The report identifies biases in the tag application and carcass recovery samples and discusses their potential impact on the population estimates. It concludes with recommendations for the improvement of study design, including improved allocation of sampling effort, resurvey procedures, the assessment of disk tag loss and handling stress, and the need to develop independent estimates of the river and lake populations.

RÉSUMÉ

Schubert, N.D., and B.P. Fanos. 1997. Estimation of the 1994 Chilko River and Chilko Lake sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2428: 54 p.

En 1986, la Commission internationale des pêcheries de saumon du Pacifique chargeait le ministère des Pêches et des Océans (MPO) d'évaluer l'échappée des stocks de saumon rouge (*Oncorhynchus nerka*) du Fraser. Le MPO a adopté le système d'estimation à deux niveaux de la Commission, selon lequel les grandes échappées (25,000 et plus) ont été évaluées aux barrières de dénombrement ou par des opérations de marquage-recapture, et les petites échappées (moins de 25,000) ont été évaluées par des techniques visuelles.

Le réseau de la rivière Chilko est fréquenté par quatre stocks de saumons rouges qui frayent dans la Chilko et la Taseko, et dans les extrémités nord et sud du lac Chilko; depuis 1943, l'échappée annuelle de ces stocks est supérieure à 25,000 saumons. L'aire d'étude de 1994 comprenait les populations de la Chilko et des extrémités nord et sud du lac Chilko. Les saumons rouges ont été capturés au cours de leur migration dans la Chilko, à un point situé à proximité de la limite inférieure des frayères; 3,638 saumons ont été libérés après marquage avec des disques. Les frayères ont été surveillées pendant la période de fraye et de mortalité massive. On a récupéré 102,030 carcasses, dont 819 portaient un disque. L'échappée de l'aire d'étude de 1994 a été évaluée, par l'estimateur de Petersen combiné, à 187,684 mâles adultes, 261,131 femelles adultes et 1,477 jeunes saumons précoces (mâles ou femelles d'âges 4₃ et 3₂).

Les auteurs du rapport ont décelé des biais dans les échantillons destinés au marquage et dans les échantillons de carcasses récupérées; ils analysent l'impact que ces biais pourraient avoir sur les estimations de la population. Leurs conclusions comportent des recommandations visant l'amélioration de la conception de l'étude, notamment une meilleure allocation de l'effort d'échantillonnage, des méthodes pour répéter l'étude, l'évaluation de la perte de disques et du stress dû à la manipulation des poissons, et la nécessité de mettre au point des estimations indépendantes des populations des rivières et du lac.

INTRODUCTION

The accurate estimation of spawning escapement has long been recognized as an essential element in the management of Fraser River sockeye salmon (*Oncorhynchus nerka*) (Thompson 1939; Howard 1948). The International Pacific Salmon Fisheries Commission (IPSFC) developed a two-tiered system whereby the estimation method selected for each stock was based on the number of spawners expected to return to the spawning grounds in a given year. For stocks with large expected returns (more than 25,000), enumeration fences and mark-recapture studies were used because they provided the statistically defensible estimates which were required to determine if system-wide precision objectives were met. For stocks with small expected returns (less than 25,000), a variety of stock-specific visual estimation methods were used (Andrew and Webb MS 1987). The IPSFC system was adopted by the Department of Fisheries and Oceans (DFO) in 1986 and remains largely in place throughout the Fraser River watershed.

The Chilko River system supports four sockeye salmon stocks which spawn in the Chilko and Taseko rivers and the north and south ends of Chilko Lake (Fig. 1). These stocks do not exhibit a quadrennial escapement cycle, although escapements on the 1916-1992 and 1915-1991 cycles tend to be larger than in other years (Appendix 1). Escapements to the Chilko River and the north end of Chilko Lake have been documented since 1909 (Babcock 1910). Although the annual assessment techniques varied, most treated the river and north lake stocks as a single population. Mark-recapture studies were first implemented on this population in 1940 (Anon. 1943) and have been conducted in almost every subsequent year. In contrast, the south lake population, although known to exist since the 1940's, was not assessed until 1971 when it was first recognized as a distinct stock (Saito and Woodey MS 1973). A mark-recapture study was conducted during 1971-1989 by tagging floating carcasses and recovering tagged and untagged carcasses on lake beaches. This study type was subject to large measurement errors (Cass 1989), however, and was replaced in 1990 by one which treated the river and lake stocks as a single population. The Taseko stock is small

relative to those in the Chilko and has been assessed using visual methods.

The 1994 study estimated the aggregate sockeye salmon escapement to the Chilko River (excluding an artificial spawning channel) and the north and south ends of Chilko Lake. Escapement to the Taseko system was estimated visually and is reported in Schubert (1997). The current report provides the first published documentation of the study design, field methods, analytic techniques and results of the Chilko sockeye escapement estimation study. Included are estimates of the age and length of adults and jacks, and escapement by sex. The report concludes with a discussion of the results and recommendations for the design of future studies.

STUDY AREA

The Chilko system, consisting of Chilko River and Lake, Taseko River and Lake, and a number of smaller tributaries, is located on the eastern edge of the Coast Mountain Range in central British Columbia (Fig. 1). Chilko Lake is 65 km long and is located at an elevation of 1,170 m in a glacial trench surrounded by steep mountains. It is situated in Ts'yl-os Provincial Park, a 233,200 hectare Class A park which was established in 1994. The lake is drained by the Chilko River, which flows northeast for 82 km, entering the Chilcotin River 106 km upstream from the Fraser River. The Chilcotin River then flows southeast, joining the Fraser River west of Williams Lake, 440 km upstream from the ocean. The Chilko River at the Chilko Lake outlet has a mean daily discharge of $41 \text{ m}^3 \cdot \text{s}^{-1}$ (1928-1990), with mean daily maxima ($110 \text{ m}^3 \cdot \text{s}^{-1}$) and minima ($9 \text{ m}^3 \cdot \text{s}^{-1}$) occurring in July and March, respectively (Environment Canada 1991). The mean daily discharge doubles to $87 \text{ m}^3 \cdot \text{s}^{-1}$ (1927-1990) by the time the Chilko joins the Chilcotin River near Redstone.

The 1994 study area included the Chilko River, from the lake outlet to Henry's Bridge, and all of Chilko Lake. River access is provided, at Henry's Bridge, Lingfield Creek and along reaches 1-5, by a gravel road which parallels the river to the west. Except for roads near Nemaia and Tsuniah creeks, Chilko Lake is accessible only by boat or aircraft.

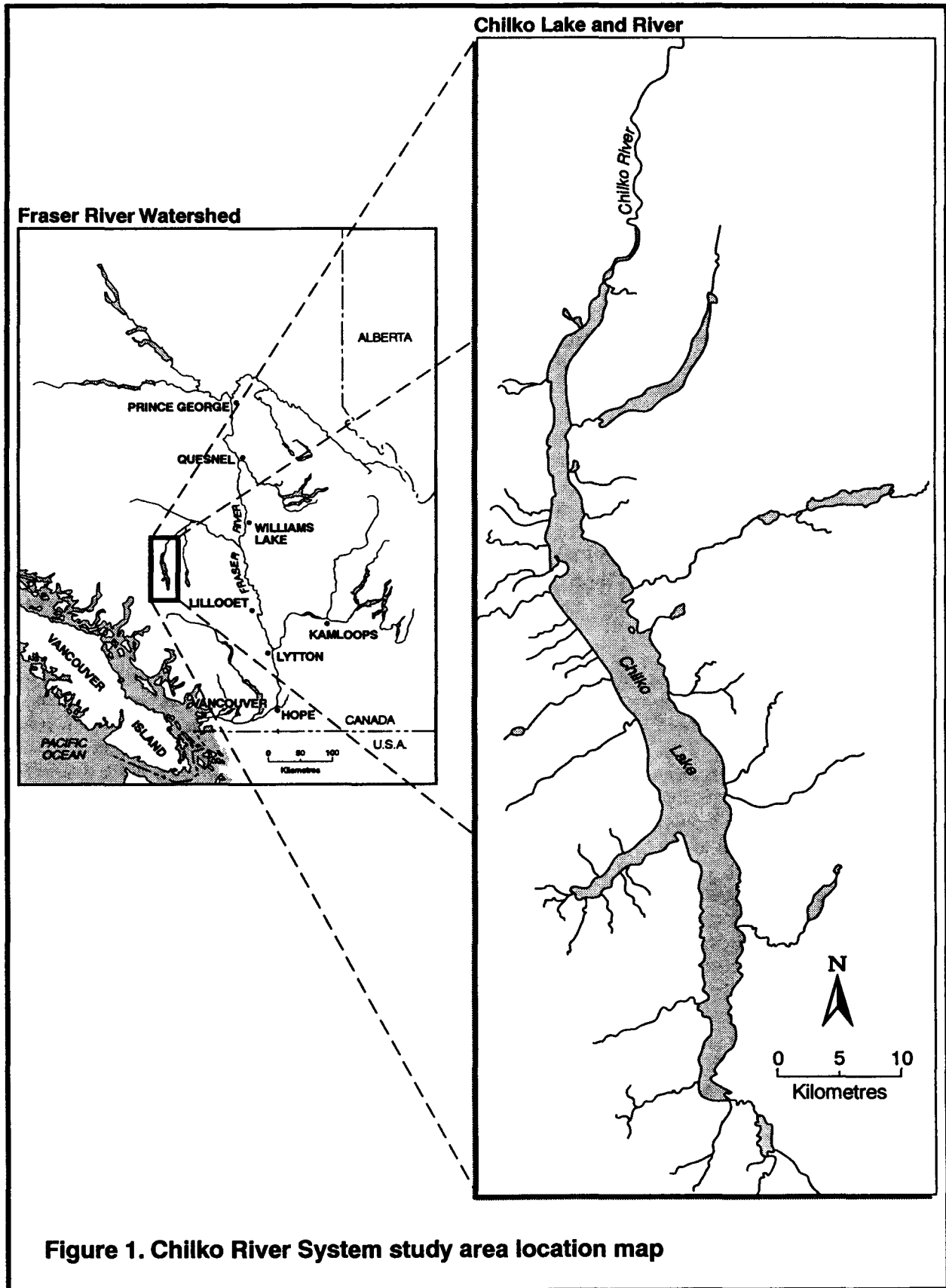
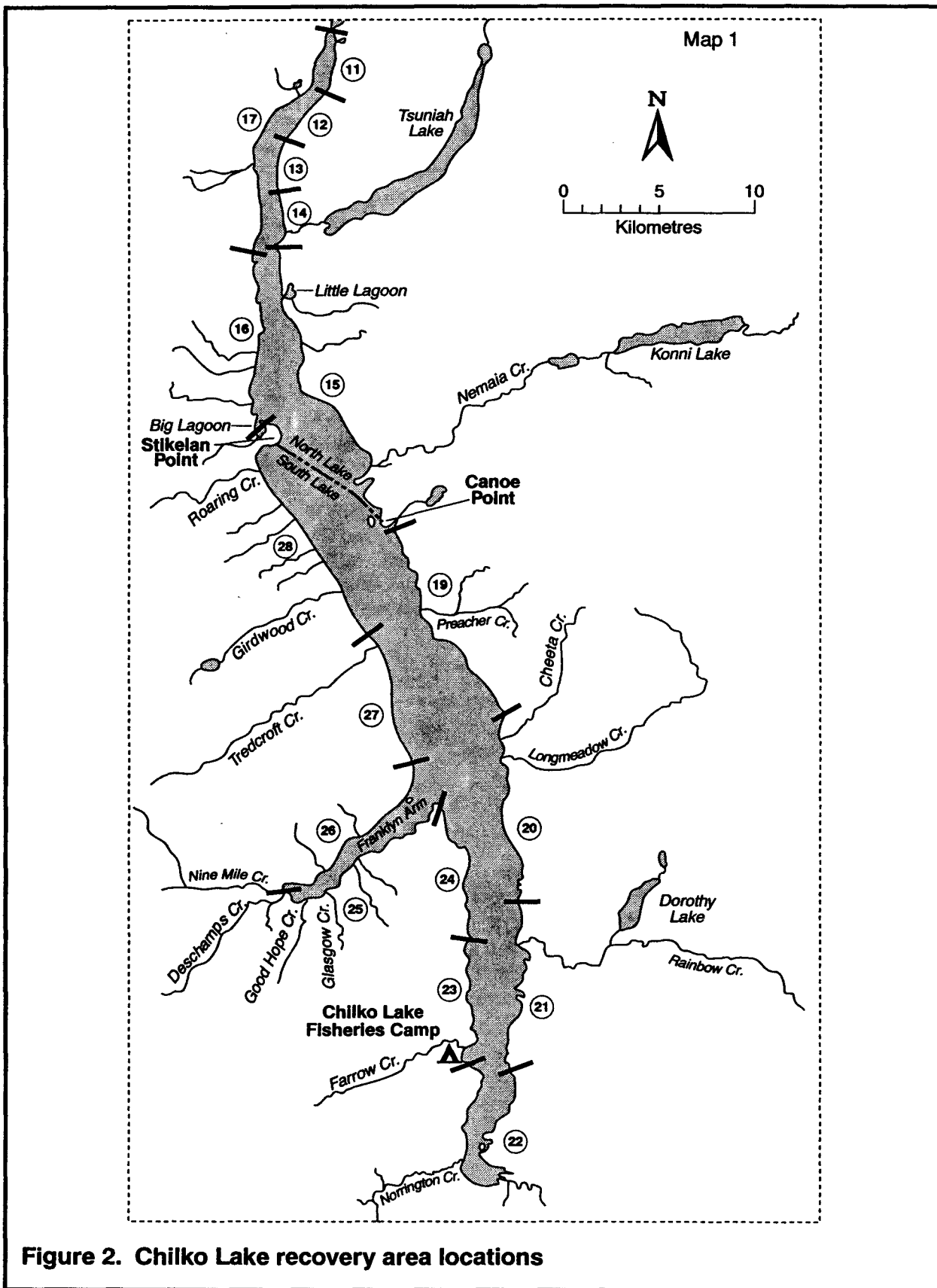


Figure 1. Chilko River System study area location map



Chilko Lake was divided into north and south areas delineated by a line drawn from Stikelon Point to Canoe Point (Fig. 2). Each area was further divided into seven and ten sections, respectively, to permit the recording of carcass recoveries by geographic location. The recorded distribution does not reflect the spawning distribution, however, because floating carcasses can drift considerable distances from their original spawning locations. Spawning occurs along the lake periphery on submerged beaches, most of which are near creek mouths or along debris slides. Spawning is scattered throughout the lake; however, three areas are known to support heavy spawning: south of Franklyn Arm, especially on the east shore across from Farrow Creek; on the north side of Franklyn Arm; and on the east shore north of Tsuniah Creek (Fig. 2).

The majority of the study area's sockeye population spawns in the upper reaches of the Chilko River. The river spawning area was divided into eight sections (Fig. 3) loosely based on homogeneity of physical characteristics, but also on the need to facilitate the data aggregations required for bias testing:

Reaches 1-4 support the bulk of sockeye spawning in the Chilko River. Reach 1 (1.2 km) extends from the lake downstream to the DFO camp. This reach is separated from Chilko Lake by a short narrows which has a depth of over 10 m. Below the narrows, there is a broad basin with a width of 500 m and a depth of 2-4 m; the substrate is mud and sand. The remainder of the reach has a depth of 1-2 m and a cobble substrate. A 300 m long island splits the middle part of the reach into two channels, and a 20-50 m wide shelf extends along the east shore from the island downstream to the end of the reach.

Reach 2 (0.6 km) extends from the DFO camp to immediately above a large pool, locally known as Blue Lagoon, located on the east side at the upstream end of the artificial spawning channel. The river morphology is similar to Reach 1, but the gradient is higher and the substrate has more boulders.

Reach 3a consists of Blue Lagoon, a 50 m diameter, 4 m deep pool which is separated from the main channel by a small island. Water velocity is low, and moribund fish collect in this area.

Reach 3b (0.9 km), which has a river morphology and a sockeye spawning density similar to Reach 2, extends downstream to the mouth of the spawning channel.

Reach 4 (0.6 km) extends downstream to a lake-like area locally known as Canoe Cross. This reach is a transition area where the gradient declines and the substrate changes from cobble to gravel, sand and mud. Sockeye spawning is relatively light.

Reach 5 (1.9 km) consists of Canoe Cross, where the river width is 300 m, water velocity is almost zero and the substrate is sand and mud with gravel and cobble in isolated areas. Although spawning occurs in isolated areas along each shore, most of the carcasses drift into this section from upstream areas.

Reach 6 (4.5 km) extends from Canoe Cross to Lingfield Creek. The channel gradient is higher than in the upper reaches, and the river is characterized by riffles, boulder and cobble. Sockeye spawning is light.

Reach 7 (4.4 km) extends from Lingfield Creek to Henry's Bridge. The channel is braided, and the gradient tends to be higher than immediately upstream. Sockeye spawning is light.

Reach 8 extends from Henry's Bridge to downstream from an area locally known as the Islands. The flood plain in this area is wider and the river braids and forms several side channels. Sockeye spawning is light.

FIELD METHODS

BRIDGE COUNTS

Migrating sockeye and chinook (including previously tagged fish) were counted during the period of sockeye immigration by an observer stationed on the east side of Henry's Bridge (Fig. 3). Fifteen minute counts were made every half hour from 8:30 a.m. until 3:45 p.m. The daily migration was then estimated as the product of the mean daily count and an expansion factor (108) developed, but not documented, by the IPSFC. These estimates provided the fishery managers with daily run timing and abundance information, and were used to set daily tag application targets at the Lingfield Creek site.

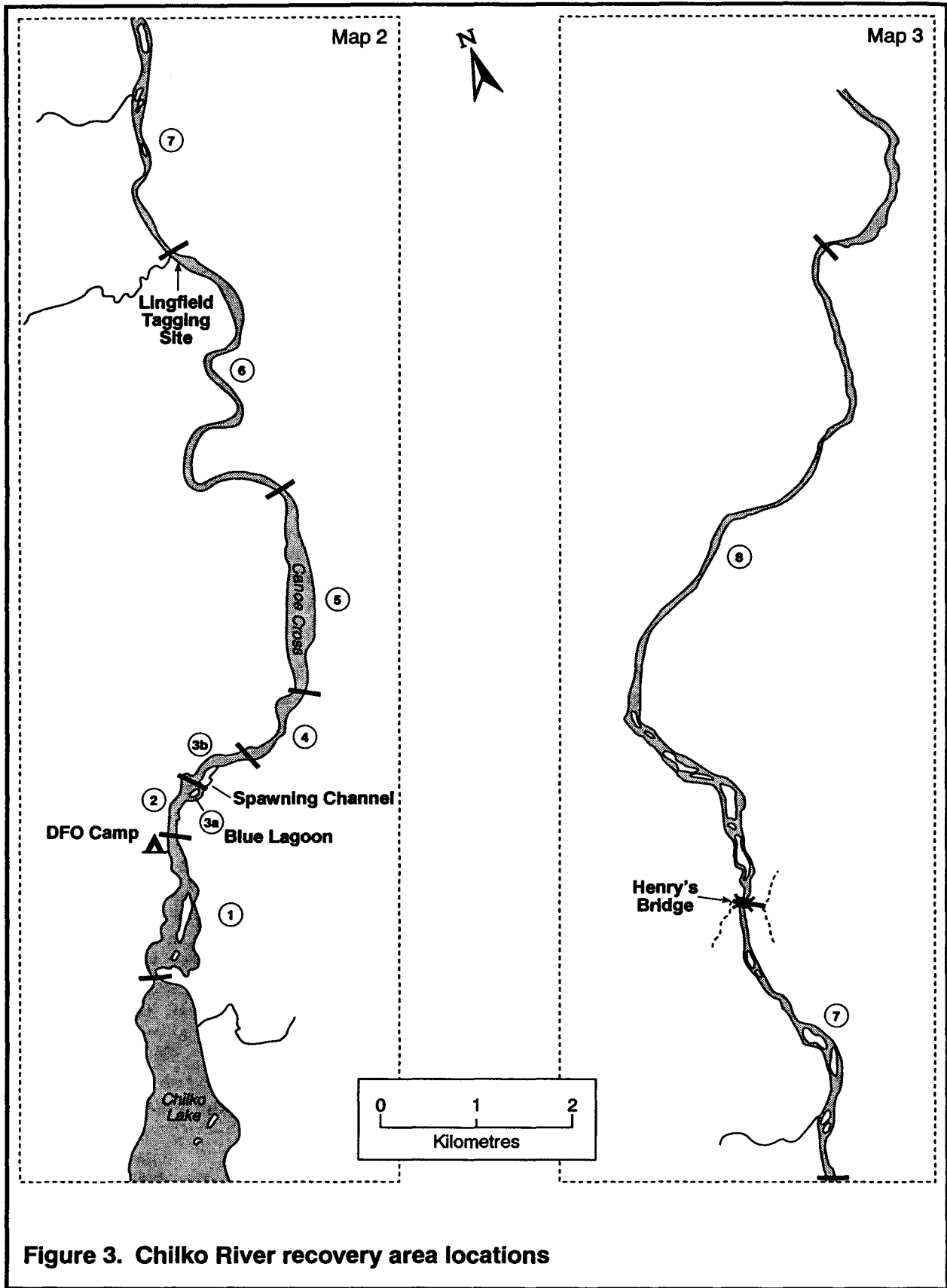


Figure 3. Chilko River recovery area locations

TAG APPLICATION

The study objective was to apply tags to 1% of the sockeye population as it migrated past the tagging site located in the Chilko River 100 m upstream from Lingfield Creek (Fig. 3). Daily tagging targets were set at about 1% of the previous days migration as estimated at Henry's Bridge. Sockeye were captured using either a 53 m x 7.5 m x 5 cm-mesh (east shore) or a 64 m x 7.5 m x 5 cm-mesh (west shore) beach seine net. Each net was set from a power boat in a downstream arc and withdrawn from the river to enclose a small area of water along the river bank. Captured fish were held in the net until removed for tagging and release. The crew alternated from one side of the river to the other because the capture and tagging activity deflected the migrating fish to the opposite shore.

Capture began shortly after the daily mean 15-minute count at Henry's Bridge exceeded 100 sockeye, and continued until the total daily count again approached 100 sockeye. Sockeye were also captured 300 m above the DFO camp in Reach 1 early in the study. Tagging in the upper river was necessary because the early component of the run had migrated past Lingfield Creek into the upper river before the start of tagging.

Sockeye which were damaged or showed advanced stages of maturation were released untagged. For previously tagged fish, the tag number was recorded and the tag was checked; if loose, the fish was retagged with the same disk. The remainder were removed from the net and marked with Petersen disk tags in a wooden tray (12 cm x 20 cm x 100 cm) constructed with a flexible plastic bottom and a metre stick recessed in one side; the tray was set in a stand elevated above the water surface. The tags consisted of two red 15 mm diameter laminated cellulose acetate disks threaded through centrally punched holes onto a 77 mm long nickel pin. The pin was inserted with pliers through the musculature and pterygiophore bones approximately 12 mm below the anterior portion of the dorsal fin insertion. The disk tags, arranged with one on each side of the fish, were secured by twisting the pin into a double knot. One disk per pair was numbered with a unique code; no secondary marks were applied. Date and location (reach) of capture, disk tag number, nose-fork (NF) length (± 0.1 cm), sex (fish with a NF length

less than 50 cm were recorded as jacks) and marks (troll, gill net, lamprey or *Flexibacter columnaris* scars) were recorded for each fish released with a disk tag. Condition at release was recorded as 1 (swam away vigorously), 2 (swam away sluggishly) or 3 (required ventilation).

SPAWNING GROUND SURVEYS

Study Area

Chilko Lake: Surveys of all known spawning areas in Chilko Lake (Fig. 2) were attempted once per week when weather permitted. Carcasses floating within a few hundred metres of shore were recovered by boat, while those along the shore were recovered on foot. All were enumerated (except predator kills, which were excluded from the survey) and either cut in two with a machete and returned to the lake or thrown above the high water mark. Carcass recoveries were recorded by date, section, sex, mark status, carcass condition (fresh, tainted or rotten) and female spawning success (0%, 50% or 100% spawned). If a disk tag was present, it was retrieved before the carcass was removed from the study area. The south end of the lake was surveyed less frequently than the north end and the river because access was limited by weather and distance. A temporary camp located at Rainbow Creek was used to accommodate up to three crew members during the 3-4 day survey.

Chilko River: The Chilko River from the Chilko Lake outlet to Henry's Bridge (Fig. 3) was surveyed on foot every 2-3 days. The surveys began when the first carcass was observed and continued until the die-off was complete. The shores were surveyed on foot, with the surveyor wading into the river to waist depth in deep water areas such as Canoe Cross; carcasses which were beyond the range of shore recovery were excluded from the study. All carcasses were recorded as above, and were either cut in two with a machete or thrown above the high water mark.

Resurvey: Previously processed carcasses were resampled throughout the recovery period to estimate the number of tagged carcasses which had not been identified correctly. The resurvey, conducted by an experienced technician, recorded carcasses by date, reach, sex and

mark status. The lake was not resurveyed because carcasses which had been cut in two tended to sink.

Spawning Channel

The spawning channel was surveyed every 1-3 days using the procedures described for the Chilko River. All fish which entered the channel were recovered as carcasses and removed from the channel.

BIOLOGICAL SAMPLING

Biological samples were obtained following a protocol provided by the Pacific Salmon Commission. Fifty females, killed during the peak of arrival at Lingfield Creek, were sampled for nose-hypural plate (standard length) length (± 0.1 cm), otoliths and scales (one from the preferred region, as defined by Clutter and Whitesel (1956)), and the egg skeins and loose eggs were removed and preserved in a 10% formaldehyde solution.

Adult carcasses were sampled as above for length (standard and postorbital-hypural plate (POH)), otoliths and scales. The adults were sampled as follows: 60 river carcasses of each sex were sampled ten days before, during, and ten days after the peak die-off; and 60 north lake and 120 south lake carcasses of each sex were sampled through the recovery period. Up to 230 river jacks and all lake jacks were sampled for standard length and scales.

ANALYTIC PROCEDURES

TESTS FOR SAMPLING SELECTIVITY

A bias profile was developed by evaluating five potential biases, temporal, spatial, fish size, fish sex and handling stress. Statistical tests were performed to assess whether the conditions of equal probability of capture, complete mixing, and simple random recovery sampling were violated (Seber 1982; p 434-9). Biases were treated in three ways. First, sex-related biases are common in mark-recapture studies and were addressed by stratifying the data by sex. Second, stress-related biases were treated by removing the high stress group from the application sample. Third, the severity of temporal or spatial biases was evaluated by comparing the simple or

pooled Petersen estimates with those calculated using Darroch's (1961) and Schaefer's (Ricker 1975) stratified models. A stratified model was used if the confidence limits did not overlap.

Period

Temporal bias was examined in two ways: a) linear regressions of tagged and untagged sockeye were fitted to data stratified in 5-day intervals. Residuals from the regression were examined to assess temporal trends in recovery rates of tagged fish as an indicator of unequal recapture probabilities; and b) chi-square tests were performed on application and recovery data stratified by equal periods, approximately equal effort (numbers of sets or passes through the sampling area), and approximately equal numbers of sockeye tagged or recovered.

Application sample bias (unequal probability of capture) was assessed by stratifying the recovery sample as above and comparing the mark incidence among recovery strata, where mark incidence was the proportion of the fish marked with a disk tag. Recovery sample bias (nonrandom sampling in the recovery sample) was assessed by stratifying the application sample as above and comparing the proportions recovered among application strata.

Location

Spatial bias was similarly assessed using chi-square tests. Application sample bias was assessed by stratifying the recovery data into geographically discrete groups which allowed sufficient sample sizes in each stratum; mark incidences in each stratum were compared. Recovery bias was examined by stratifying the application sample by reach and comparing proportions recovered.

Fish Size

Size related bias was assessed using the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981). Application bias could not be assessed because the untagged carcasses were not sampled for length. Recovery bias was examined by partitioning the application sample into recovered and nonrecovered components and comparing the NF length-frequency distributions of each.

Fish Sex

Sex related bias was assessed using a chi-square test. Application bias was examined by comparing the sex ratio of the marked and unmarked spawning ground recoveries. Recovery bias was examined by partitioning the application sample into recovered and non-recovered components and comparing the sex composition in each.

Stress

Potential bias resulting from handling and tagging stress was assessed in two ways. First, three tests were performed to determine whether specific tags should be excluded from the application sample: a) fish with less than five days between tag application and recovery were removed from the samples; b) the sample was partitioned into fish which required ventilation at release and those which did not. If a chi-square test showed a significant difference in the proportions recovered, the high stress group was removed from the samples; and c) an identical procedure was used to evaluate fish which were recaptured in subsequent beach seine sets.

Second, two chi-square tests were performed as general indicators of a stress problem: a) percent spawning success was compared between marked and unmarked spawning ground recoveries; and b) the recovery sample was partitioned into those recovered above and below the tagging site. Disk tag incidence and the percent spawning success of tagged females was compared between each group. These tests were not used to exclude specific data from the study. Rather, they provided an indicator of whether study design changes would be required in future studies to address a systemic stress problem.

ESTIMATION OF SPAWNER POPULATION

Data Corrections

Sex Identification Error: The tag application data were corrected for sex identification error. Error occurred because the development of sexually dimorphic traits was often not advanced and internal examinations could not be made. The correction of the recovery data was unnecessary because development was complete and dead fish could be examined more carefully.

Sex identification error was corrected as described by Staley (1990):

- 1) Estimated true number of adult males released with disk tags:

$$M_m = \frac{M_m^* - (M_t R_{m,f}) / R_f}{1 - (R_{m,f} / R_f) - (R_{f,m} / R_m)}$$

where:

- M_m^* = the field estimate of the number of adult males released with disk tags;
- M_t = the total number of sockeye adults released with disk tags;
- $R_{m,f}$ = the number of adult females recovered with disk tags which were released as males;
- $R_{f,m}$ = the number of adult males recovered with disk tags which were released as females;
- R_f = the number of adult females recovered with disk tags;
- R_m = the number of adult males recovered with disk tags.

- 2) Estimated true number of adult females released with disk tags:

$$M_f = M_t - M_m$$

Tag Recognition Error: Resurvey data were used to correct the recovery totals for disk tags which were missed in the initial survey. The following was calculated by sex:

- 3) Estimated true number of disk tags recovered, corrected for disk tags missed on the initial survey:

$$R_{cor} = R_{is} + ((R_{rs} / C_{rs}) \cdot C_{is})$$

where:

- R_{is} = the number of disk tags recovered on the initial survey;
- R_{rs} = the number of disk tags recovered on the resurvey;
- C_{rs} = the number of carcasses examined on the resurvey;
- C_{is} = the number of carcasses examined on the initial survey.

Spawning Channel Recoveries: The 1994 escapement to the spawning channel was assessed by a complete census and, therefore, was not part of the mark-recapture study area. Disk tags recovered in the channel, therefore, were removed from the application sample.

Population Estimator

The escapement estimates were calculated from the mark-recapture data using: a) the simple or pooled Petersen estimator (Seber 1982; p 60); and b) the Darroch (Seber 1982; p 431-445) and Schaefer (Seber 1982; p 439) estimators for stratified populations. Total escapement (adults and jacks) was calculated as follows:

- 4) Estimated Chilko River system sockeye escapement:

$$N_t = N_m + N_f + N_j$$

where:

- N_m = the adult male escapement estimate;
- N_f = the adult female escapement estimate;
- N_j = the jack (male and female) escapement estimate.

Pooled Petersen Estimator: The pooled Petersen estimator was used to estimate the 1994 Chilko River system escapement unless biases were identified which required the stratification of the data set.

- 5) Pooled Petersen estimate of the escapement of male adults:

$$N_m = \frac{(M_m + 1)(C_m + 1)}{(R_m + 1)}$$

where:

- M_m = the number of adult males released with disk tags;
- C_m = the number of adult male carcasses examined for disk tags;
- R_m = the number of adult males recovered with disk tags.

The female and jack escapements were calculated analogous to the above.

- 6) Variance of the pooled Petersen population estimate was calculated as follows:

$$V_t = V_m + V_f + V_j$$

= variance of the estimate;

$$V_m = \frac{(N_m^2)(C_m - R_m)}{(C_m + 1)(R_m + 2)}$$

= variance of the adult male escapement estimate;

$$V_f = \text{variance of the female escapement estimate (as above);}$$

$$V_j = \text{variance of the jack escapement estimate (as above).}$$

Ninety-five percent confidence limits were calculated for the male, female, jack and total population estimates as follows:

$$N \pm 1.96 \sqrt{V}$$

Stratified Estimators: When spatial or temporal biases were identified, stratified estimates were calculated using Schaefer's and Darroch's estimators. The pooled Petersen was the preferred estimator because precision is generally higher; however, if the confidence intervals of the pooled and the stratified estimates did not overlap, the bias was judged to be severe and the stratified estimator was considered more appropriate. Variance estimation procedures have not been developed for the Schaefer estimator. The variance of the stratified Darroch estimator was calculated using the procedures described by Seber (1982; page 433).

Alternate Jack Population Estimator

If fewer than five disk tags were recovered, the jack population (where jacks were defined as fish with a NF length of less than 50 cm regardless of sex) was estimated as the product of the number recovered, an expansion factor developed from previous IPSFC studies, and the inverse of the 1994 recovery rate of Chilko adult males:

- 7) Estimate of the escapement of jacks when fewer than five disks were recovered:

$$N_j = \frac{C_j \cdot 1.26}{R_m / M_m}$$

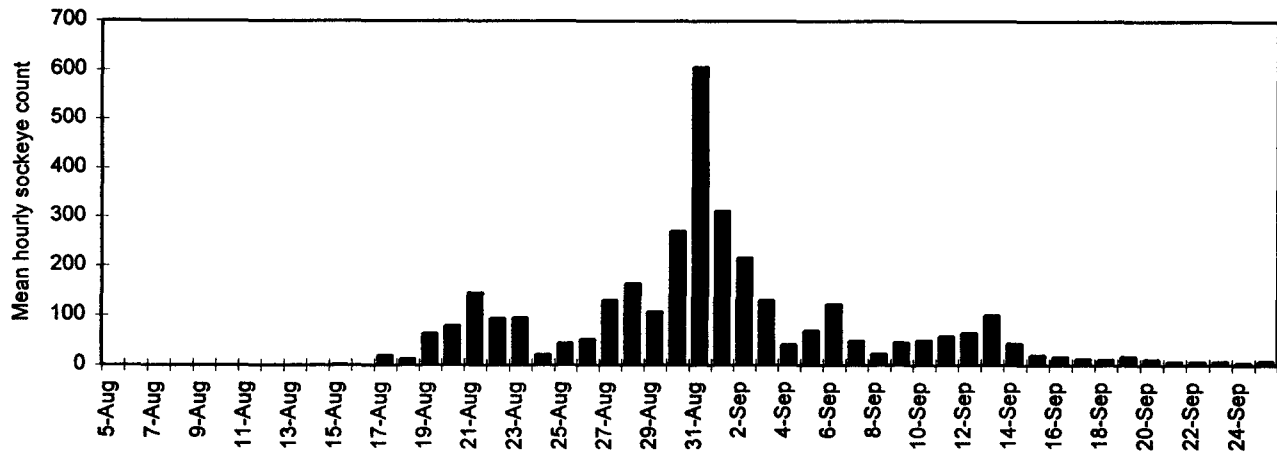


Figure 4. Daily mean 15-minute counts of sockeye salmon adults migrating past Henry's Bridge in the Chilko River, 1994

where:

C_j = the number of jacks recovered on the spawning grounds.

FECUNDITY ESTIMATION

Mean fecundities were calculated for ages 4₂ and 5₂ as follows:

8) Estimated mean fecundity of age class *a*:

$$\bar{F}_a = \frac{\sum (f_{ai}/w_{ai})W_{ai}}{n_a}$$

where:

- f_{ai} = the number of eggs in a weighed subsample (w_{ai}) of fecundity sample *i* of age *a* females;
- w_{ai} = the weight, in grams, of a subsample of fecundity sample *i* of age *a* females;
- W_{ai} = the weight, in grams, of fecundity sample *i* of age *a* females;
- n_a = the number of age *a* females sampled for fecundity.

RESULTS

BRIDGE COUNTS

Daily counts of sockeye and chinook salmon migrating past Henry's Bridge were conducted for

15 minutes every half hour from 8:30 a.m. to 3:45 p.m. (Appendix 2); the daily mean 15-min. sockeye count is presented in Figure 4. Sockeye were first observed on August 7. The peak migration was observed from August 30 to September 2, and the migration was virtually complete by late September. Very little hourly variation was noted. One previously tagged sockeye was observed migrating upstream; none were observed moving downstream.

TAG APPLICATION

Disk tags were applied to 3,603 sockeye adults and 67 jacks from August 22 to September 20, 1994 (Appendix 3). Most (89%) of the tags were applied at Lingfield Creek, with the remainder applied in the upper river early in the study. This was necessary because tag application began after the immigration was underway; therefore, these fish had moved into the upper river before the start of tagging.

The application data were first adjusted for sex identification error. The sex of 8.1% (23) of the males and 10.9% (51) of the females was recorded incorrectly at the time of tagging. When adjusted for this error, an estimated 1,386 (38.6%) males and 2,201 (61.4%) females were released with disk tags. The data were then tested to determine if specific tags should be excluded from subsequent analyses. First, fish with less than five days between tag application and recovery were removed from the application

Table 1. Disk tags applied, carcasses examined and marks recovered, by sex, for Chilko River system sockeye salmon, 1994. ^a

Sex	Disk tags applied ^b	Carcasses examined	Marks recovered				Total	Percent recovered
			Disk tag and secondary mark ^c	Secondary mark only ^c	Disk tag only	Resurvey adjustment		
Male	1,381	41,963	0	0	278	30	308	22.3%
Female	2,190	59,829	0	0	459	42	501	22.9%
Jack	67	238	0	0	10	0	10	14.9%
Total	3,638	102,030	0	0	747	72	819	22.5%

^a Excludes carcasses recovered in the spawning channel.

^c Secondary marks were not applied in 1994.

^b Corrected for sex identification errors.

sample. None were detected; however, we note that the delay between the start of tagging (August 22) and recovery (September 9) would have prevented the detection of such fish early in the study. Second, the sample was partitioned into fish which required ventilation at release and those which did not. Fourteen adults (0.4%) and two jacks (3.0%) required ventilation; however, the proportions of these groups recovered (21.4% and 0.0%, respectively) were not significantly different ($P > 0.05$; chi-square) from the nonventilated fish (20.6% and 15.4%). Consequently, they were not removed from the application sample. Third, an identical procedure evaluated fish which were recaptured in subsequent beach seine sets. Because tags were applied to migrating sockeye which quickly cleared the tagging site, only four were recaptured (Appendix 3) and none were recaptured more than once. The proportion recovered (50.0%) was considerably higher in this group, but was not significantly different ($P > 0.05$; chi-square) from the non-recaptured fish (33.8%); consequently, they were not removed from the application sample.

The final corrected disk tag application sample, excluding 5 males and 11 females which were recovered in the spawning channel (Appendix 5d), totalled 1,381 males, 2,190 females and 67 jacks (Table 1).

The mean NF length of males, females, jacks and jills was 59.1 cm, 57.1 cm, 44.9 cm and 46.5 cm; none were scale sampled. The incidence of net, lamprey, hook and *Flexibacter columnaris* scars was 27%, 6%, 7%, and 3% in

males, 43%, 4%, 5% and 5% in females, and 28%, 0%, 0% and 5% in jacks (Appendix 4).

SPAWNING GROUND SURVEYS

Study Area

In 1994, 101,792 sockeye adults and 238 jacks were recovered in the study area from September 5 to October 22 (Table 1; Appendix 5). Of the adults, 41% were male and 59% were female, and 0.7% and 0.8% had a disk tag. The jack disk tag incidence was 4.2%. Female spawning success averaged 97.1% (Table 2).

Chilko Lake: The north end of Chilko Lake was surveyed an average of seven times (frequency varied between sections) from September 17 to October 18 (Appendix 5a). The north end of Chilko Lake accounted for 18% (18,132) and 43% (103) of the adult and jack carcasses, respectively; 0.45% and 4.85% had disk tags. The average time between release and recovery for disk tagged males, females and jacks was 29 days, 31 days and 32 days, respectively, and was longer among those tagged earlier in the study (Table 2). None of the tagged fish were out for less than 10 days. Female spawning success averaged 97.4%, with lower success among the early spawners (Table 2). The most important recovery sections were A1 (5% of the total recovery) and B1 (4%) (Fig. 2).

The south end was surveyed an average of four times from September 17 to October 12 (Appendix 5b). South end surveys were often ham-

Table 2. Average elapsed time between tag application and recovery, and female spawning success, by recovery section, period and sex, in the Chilko River system, 1994.

Recovery location	Period ^a	Time out between tag application and carcass recovery (days)			Female spawning success
		Male	Female	Jack	
Study Area Total	Early	30.5	31.4	31.5	87.5%
	Late	26.7	27.2	18.5	98.6%
	Total	28.6	28.5	26.3	97.1%
- Chilko River	Early	31.0	31.5	27.0	83.9%
	Late	26.7	27.5	16.7	98.5%
	Total	28.7	28.6	20.8	97.0%
- North Chilko Lake	Early	29.8	33.5	37.8	94.1%
	Late	27.9	27.6	24.0	97.7%
	Total	29.2	31.0	31.8	97.4%
- South Chilko Lake	Early	29.0	34.7	-	92.3%
	Late	-	-	-	99.6%
	Total	29.0	34.7	-	97.2%
Spawning Channel	Early	21.0	8.0	-	18.6%
	Late	22.0	14.1	-	95.8%
	Total	21.4	12.5	-	36.7%

^a Time out to recovery: early = August releases; late = September releases.

Female spawning success: early = recovered to September 24; late = recovered after September 24.

pered by high winds which had the combined effect of reducing survey frequency by restricting boat access, and reducing survey effectiveness by making the sighting of floating carcasses more difficult and by burying beached carcasses in sand and gravel. The south end of Chilko Lake accounted for 2% (1,593) and 20% (48) of the adult and jack carcasses, respectively; 0.25% and 0.00% had disk tags. The average time between release and recovery for disk tagged males and females was 29 days and 35 days, respectively (Table 2). None of the tagged fish were out for less than 10 days. Female spawning success averaged 97.2%, with lower success among the early spawners (Table 2).

Chilko River: The Chilko River was surveyed an average of 17 times from September 5 to October 22 (Appendix 5c). The river accounted for 81% (82,067) and 37% (87) of the adult and jack carcasses, respectively; 0.79% and 5.75% had disk tags. The average time between release and recovery for disk tagged males, females and jacks was 29 days, 29 days and 21 days, respectively, and was longer among those

tagged earlier in the study (Table 2). Only 1 fish, a jack, was out for less than 10 days. Female spawning success averaged 97.0%, with lower success among early spawners (Table 2). The most important recovery areas were reaches 5 (34% of the total recovery), 3b (9%) and 6 (8%).

Resurvey: The river and north lake spawning areas were resurveyed an average of three times from September 21 to October 19 (Appendix 6); 8,516 males, 12,699 females and 23 jacks were reexamined, and 6, 9 and 0 disk tags were recovered. An estimated 30 (9.7%) and 42 (8.4%) disk tagged adult males and females processed during the main survey were not correctly identified as tagged fish (Table 1). When corrected for this error, a total of 308 adult male and 501 female disk tags were recovered, a disk tag incidence of 0.73% and 0.84%, respectively.

Spawning Channel

The spawning channel was surveyed 23 times from August 30 to October 1 (Appendix 5d). Recoveries totalled 791 males, 1,139 fe-

Table 3. Percent at age and mean POH length at age in Chilko River and north and south Chilko Lake sockeye sampled on the spawning grounds, 1994. ^a

Recovery location	Sex	Percent at age					POH length (cm) at age				
		3 ₂	4 ₃	4 ₂	5 ₂	5 ₃	3 ₂	4 ₃	4 ₂	5 ₂	5 ₃
Chilko River	Male	0%	0%	96%	4%	0%	-	-	47.2	52.1	-
	Female	0%	0%	98%	2%	0%	-	-	46.2	51.8	-
	Jack	86%	10%	4%	0%	0%	35.6	36.4	41.5	-	-
North Chilko Lake	Male	0%	0%	100%	0%	0%	-	-	46.1	-	-
	Female	0%	0%	100%	0%	0%	-	-	45.7	-	-
	Jack	83%	14%	3%	0%	0%	35.0	35.8	43.0	-	-
South Chilko Lake	Male	0%	8%	86%	1%	5%	-	38.3	44.8	53.2	46.7
	Female	0%	11%	89%	0%	0%	-	37.6	44.7	-	-
	Jack	10%	90%	0%	0%	0%	34.8	35.7	-	-	-

^a True jacks are ages 3₂ and 4₃; overlap in the jack and adult distributions (50 cm NF cut-off) resulted in some misclassification.

males and 17 jacks, of which 5 (0.63%), 11 (0.97%) and 0 (0.00%), respectively, had disk tags. The average time between release and recovery for disk tagged males and females was 21 days and 13 days, respectively (Table 2) and, unlike the other recovery areas, was shorter among those tagged earlier in the study. Four females were out for less than 10 days, none of which had successfully spawned. Female spawning success averaged only 36.7%, with much lower success among early spawners (Table 2).

BIOLOGICAL SAMPLING

Fecundity samples from 48 age 4₂ and 2 age 5₂ females were obtained at Lingfield Creek on September 8-9 (Appendix 7). Age 4₂ females had an average standard length of 52.4 cm (range 48.4 cm to 56.9 cm) and an average fecundity of 2,614 (range 2,084 to 3,664). Age 5₂ females had an average standard length of 55.0 cm (range 54.9 cm to 55.1 cm) and an average fecundity of 2,876 (range 2,834 to 2,917).

The age composition of the adult sample was 1.8% age 5₃, 2.3% age 5₂, 2.6% age 4₃ and 93.3% age 4₂ in males, and 0.0% age 5₃, 1.1% age 5₂, 3.6% age 4₃ and 95.3% age 4₂ in females (Appendix 8a). The south lake samples were distinct from the north lake and river samples in that: a) the age structure was more complex and the sub-3 proportion (ages 4₃ and 5₃) was significantly larger in both sexes ($P < 0.05$;

chi-square); and b) average size was smaller (Table 3). No significant difference was noted in either age or size among the river and north lake samples, although more 5₂'s were recovered in the river, or among the three river samples.

The age composition of the jack sample was 2.4% age 4₂, 39.9% age 4₃ and 57.7% age 3₂ (Appendix 8b). As noted above, the proportion of sub-3 fish in the south lake population (90%) was significantly larger ($P < 0.05$; chi-square) than in either the north lake (14%) or river (10%) populations. We also note that the use of a 50 cm cutoff to separate adults and jacks introduces some error into the population estimates; 2.4% of the jack samples were actually adult (age 4₂) sockeye.

SAMPLING SELECTIVITY

Period

Temporal bias in the application sample was examined by comparing disk tag incidences in five recovery periods which were stratified in three ways: by equal periods; equal recovery effort; and equal numbers recovered (Table 4). Tag incidence in adults ranged from 0.0% to 0.9%, with an indication of a lower tag incidence early in the study. Tag incidence in jacks ranged from 0.0% to 8.0%, with a higher incidence early in the study. None of these differences were significant ($P > 0.05$; chi-square), however, in any of

Table 4a. Incidence of disk tags in sockeye salmon recovered on the Chilko River system spawning grounds, by recovery period and sex, 1994. Data are stratified by equal recovery periods. ^a

Recovery period	Number of surveys ^b	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
05-Sep to 14-Sep	1	0	1	0	125	135	0	0.0%	0.7%	-
15-Sep to 24-Sep	4	66	46	4	10,809	7,699	67	0.6%	0.6%	6.0%
25-Sep to 04-Oct	5	149	261	5	23,276	34,032	109	0.6%	0.8%	4.6%
05-Oct to 14-Oct	6	56	131	1	6,877	15,598	62	0.8%	0.8%	1.6%
15-Oct to 22-Oct	5	7	20	0	876	2,365	0	0.8%	0.8%	-
Chi-square test result:								4.11	4.19	1.59
Critical Chi-square (df = 4; $\alpha = 0.05$):								9.49	9.49	5.99

^a Excludes carcasses recovered in the spawning channel.

^b Based on recovery effort in Chilko River.

Table 4b. Incidence of disk tags in sockeye salmon recovered on the Chilko River system spawning grounds, by recovery period and sex, 1994. Data are stratified by approximately equal recovery cycles. ^a

Recovery period	Number of surveys ^b	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
05-Sep to 23-Sep	4	45	27	2	8,020	5,416	46	0.6%	0.5%	4.3%
24-Sep to 02-Oct	4	153	230	7	22,805	30,097	111	0.7%	0.8%	6.3%
03-Oct to 09-Oct	4	62	137	0	8,438	16,427	60	0.7%	0.8%	0.0%
10-Oct to 16-Oct	4	16	58	1	2,417	7,032	21	0.7%	0.8%	4.8%
17-Oct to 22-Oct	4	2	7	0	283	857	0	0.7%	0.8%	-
Chi-square test result:								1.96	6.44	3.87
Critical Chi-square (df = 4; $\alpha = 0.05$):								9.49	9.49	7.81

^a Excludes carcasses recovered in the spawning channel.

^b Based on recovery effort in Chilko River.

Table 4c. Incidence of disk tags in sockeye salmon recovered on the Chilko River system spawning grounds, by recovery period and sex, 1994. Data are stratified by approximately equal numbers of total recoveries. ^a

Recovery period	Number of surveys ^b	Carcasses recovered with disk tags			Total recovery			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
05-Sep to 24-Sep	5	66	47	4	10,934	7,834	67	0.6%	0.6%	6.0%
25-Sep to 28-Sep	2	45	72	3	7,782	8,590	51	0.6%	0.8%	5.9%
29-Sep to 01-Oct	1	54	93	2	8,966	14,259	25	0.6%	0.7%	8.0%
02-Oct to 06-Oct	3	70	136	0	8,240	15,258	60	0.8%	0.9%	0.0%
07-Oct to 22-Oct	9	43	111	1	6,041	13,888	35	0.7%	0.8%	2.9%
Chi-square test result:								6.51	9.20	4.56
Critical Chi-square (df = 4; $\alpha = 0.05$):								9.49	9.49	9.49

^a Excludes carcasses recovered in the spawning channel.

^b Based on recovery effort in Chilko River.

the three stratifications. This suggests that the objective of proportional tag application across all run segments was achieved and that temporal bias at application was not a serious concern in 1994. We are concerned, however, that an undetected bias may have occurred because tagging began several days after significant migrations were first observed at Henry's Bridge (Fig. 5). This bias may not have been detected because the recovery survey also started late (discussed later). Such a bias would be important in the Chilko study because lake spawners migrate past the tagging site earlier than river spawners. For example, lake spawners comprised up to one-quarter of the August migrants but less than 5% of the September migrants (Table 5).

Recovery bias was examined by comparing the proportions recovered from five application periods which were stratified in three ways: by equal periods; equal application effort; and equal numbers applied (Table 6). The proportion of the adults recovered ranged from 12.1% to 34.9%, with a significant ($P < 0.05$; chi-square) difference in females in all three stratifications; the proportion recovered was consistently higher among those tagged later in the study. The proportion of jacks recovered ranged from 0.0% to 57.1%; jacks tagged early in the study were recovered at a significantly ($P < 0.05$) higher rate in all three stratifications.

In their evaluation of the 1994 study data, the Spawning Escapement Estimation Working Group of the Fraser River Sockeye Salmon Management Review Team regressed tagged and untagged recoveries stratified in 5-day intervals (Anon. 1995). The Working Group reported a significantly ($P < 0.05$) positive trend in both males and females, but that the residuals from the regressions plotted by recovery period showed irregular patterns without a time trend in recovery rates. They concluded that the former indicated that at least the number of tagged fish that were sampled in a particular time period was a constant proportion of the untagged fish, but that the irregular pattern of residuals supported the chi-square result which indicated a temporal recovery bias.

Location

Spatial bias in the application sample was examined by comparing the mark incidence in

five recovery sections (Table 7). Mark incidence among adults ranged from 0.14% to 0.89%, with an incidence among lake spawners of about half that of river spawners. These differences were significant ($P < 0.05$; chi-square) in both males and females. When the lake and river recovery areas were tested separately, however, the differences were not significant in the former and were significant only among females in the latter. Mark incidences among jacks ranged from 0.00% to 10.00%; however, the difference was not significant ($P > 0.05$; chi-square).

Recovery bias was examined by stratifying the application sample into two reaches (Lingfield Creek and upper river) and comparing proportions recovered in each (Table 8). Proportions among adults ranged from 12.7% to 23.4%, with a significant ($P < 0.05$; chi-square) difference among females. This result indicates that the stock composition differed between sites. Based on the recovery distribution of tags, the Reach 6 (Lingfield Creek) sample of females had a lower proportion of north lake fish and a higher proportion of upper river fish (Table 9).

Fish Size

Application bias could not be assessed because the length of untagged carcasses was not measured. Recovery bias was examined by partitioning the application sample into recovered and nonrecovered components and comparing the NF frequency distributions. There was no difference in either sex ($P > 0.05$; Kolmogorov-Smirnov two sample test). Similar proportions recovered were also noted when the data were stratified in 3-cm NF groups (Table 10).

Fish Sex

There was no difference ($P > 0.05$; chi-square) in the sex ratio of the marked and unmarked spawning ground recoveries (Table 11). The application sample, therefore, was relatively unbiased with respect to sex.

There was no difference ($P > 0.05$; chi-square) in the sex ratio of the recovered and nonrecovered components of the application sample (Table 11). Further, no difference was noted in the proportion of males (22.3%) and females (22.9%) released with disk tags and recovered on the spawning grounds (Table 1). We

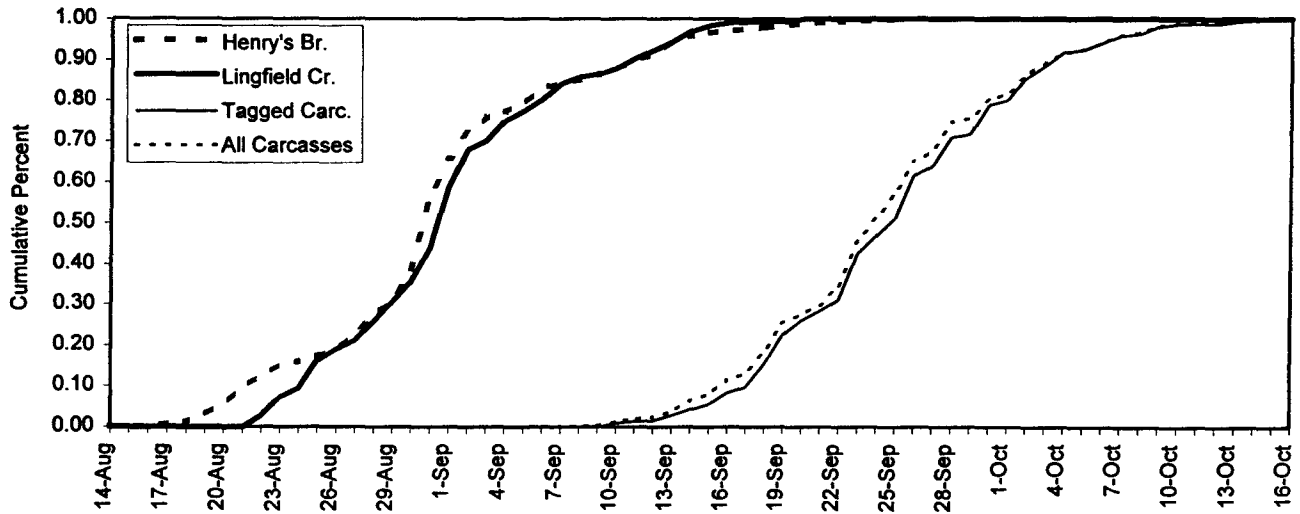


Figure 5. Comparison of the daily cumulative percent distributions of all sockeye counted at Henry's Bridge with tagged sockeye released at Lingfield Creek, and the recovery on the spawning grounds of all carcasses with disk tagged carcasses.

Table 5. Distribution of recovered disk tagged sockeye adults on the Chilko River system spawning grounds, by sex and tag application date, 1994.

		Recovery location of disk tagged carcasses											
		Lower River		Middle River		Upper River		Sp. channel		North Lake		South Lake	
Sex	Application date	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Male	22-Aug to 26-Aug	13	23%	17	30%	17	30%	1	2%	9	16%	0	0%
	27-Aug to 31-Aug	8	10%	24	30%	32	40%	2	3%	13	16%	1	1%
	01-Sep to 05-Sep	11	13%	29	34%	36	42%	2	2%	8	9%	0	0%
	06-Sep to 10-Sep	2	6%	16	50%	11	34%	0	0%	3	9%	0	0%
	11-Sep to 15-Sep	1	4%	17	63%	9	33%	0	0%	0	0%	0	0%
	16-Sep to 20-Sep	0	0%	1	100%	0	0%	0	0%	0	0%	0	0%
Female	22-Aug to 26-Aug	7	12%	16	27%	14	23%	1	2%	21	35%	1	2%
	27-Aug to 31-Aug	13	16%	39	47%	20	24%	2	2%	7	8%	2	2%
	01-Sep to 05-Sep	13	8%	60	35%	76	44%	8	5%	14	8%	0	0%
	06-Sep to 10-Sep	0	0%	34	47%	36	49%	0	0%	3	4%	0	0%
	11-Sep to 15-Sep	0	0%	31	44%	37	52%	0	0%	3	4%	0	0%
	16-Sep to 20-Sep	0	0%	7	58%	5	42%	0	0%	0	0%	0	0%

a. Section definitions: Chilko River, upper - reaches 1-4; Chilko River, middle - Reach 5; Chilko River, lower - reaches 6-7; Chilko Lake, north - A1-A5 and B1-B2. Chilko Lake, south - reaches A-J.

Table 6a. Proportion of the disk tag application sample recovered on the Chilko River system spawning grounds, by application period and sex, 1994. Data are stratified by equal application periods. ^a

Application period	Number of sets	Disk tags applied ^b			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
22-Aug to 27-Aug	40	291	468	9	63	65	5	21.6%	13.9%	55.6%
28-Aug to 02-Sep	34	670	1,000	26	131	188	1	19.6%	18.8%	3.8%
03-Sep to 08-Sep	35	234	406	11	49	101	1	20.9%	24.9%	9.1%
09-Sep to 14-Sep	25	159	241	18	30	84	3	18.9%	34.9%	16.7%
15-Sep to 20-Sep	15	27	75	3	5	21	0	18.5%	28.0%	0.0%
Chi-square test result:								0.85	51.03	15.08
Critical Chi-square (df = 4; α = 0.05):								9.49	9.49	9.49

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error.

Table 6b. Proportion of the disk tag application sample recovered on the Chilko River system spawning grounds, by application period and sex, 1994. Data are stratified by approximately equal application effort. ^a

Application period	Number of sets	Disk tags applied ^b			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
22-Aug to 25-Aug	31	218	363	7	48	44	4	22.0%	12.1%	57.1%
26-Aug to 31-Aug	27	421	567	18	86	96	2	20.4%	16.9%	11.1%
01-Sep to 04-Sep	30	409	702	15	77	148	1	18.8%	21.1%	6.7%
05-Sep to 11-Sep	32	208	345	16	46	104	1	22.1%	30.1%	6.3%
12-Sep to 20-Sep	29	125	213	11	21	67	2	16.8%	31.5%	18.2%
Chi-square test result:								2.31	54.41	11.88
Critical Chi-square (df = 4; α = 0.05):								9.49	9.49	9.49

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error.

Table 6c. Proportion of the disk tag application sample recovered on the Chilko River system spawning grounds, by application period and sex, 1994. Data are stratified by approximately equal numbers of total tags applied. ^a

Application period	Number of sets	Disk tags applied ^b			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
22-Aug to 27-Aug	40	293	466	9	63	65	5	21.5%	13.9%	55.6%
28-Aug to 31-Aug	18	346	464	16	71	75	1	20.5%	16.2%	6.3%
01-Sep to 02-Sep	16	323	537	10	60	113	0	18.6%	21.0%	0.0%
03-Sep to 06-Sep	23	165	277	10	36	64	1	21.8%	23.1%	10.0%
07-Sep to 20-Sep	52	254	446	22	48	142	3	18.9%	31.8%	13.6%
Chi-square test result:								1.39	52.90	14.62
Critical Chi-square (df = 4; α = 0.05):								9.49	9.49	9.49

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error.

Table 7. Proportion of the Chilko River system sockeye salmon spawning ground recovery sample marked with disk tags, by recovery location and sex, 1994.

Recovery location	Section ^a	Carcasses recovered with disk tags			Total carcasses examined			Disk tag incidence		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Chilko River	Upper	105	188	2	14,702	22,431	32	0.71%	0.84%	6.25%
	Middle	104	187	2	13,229	21,016	45	0.79%	0.89%	4.44%
	Lower	35	33	1	4,711	5,978	10	0.74%	0.55%	10.00%
Chi-square test result (river only):								0.49	6.57	0.39
Critical Chi-square (df = 2; α = 0.05):								5.99	5.99	5.99
Chilko Lake	North	33	48	5	8,616	9,516	103	0.38%	0.50%	4.85%
	South	1	3	0	705	888	48	0.14%	0.34%	0.00%
Chi-square test result (river and lake):								17.26	20.05	3.22
Critical Chi-square (df = 4; α = 0.05):								9.49	9.49	9.49

^a Section definitions: Chilko River, upper - reaches 1-4; Chilko River, middle - Reach 5; Chilko River, lower - reaches 6-7; Chilko Lake, north - A1-A5 and B1-B2; Chilko Lake, south - reaches A-J.

Table 8. Proportion of the disk tag application sample recovered on the Chilko River system spawning grounds, by application location and sex, 1994. ^a

Application location	Number of sets	Disk tags applied ^b			Carcasses recovered with disk tags			Percent recovered		
		Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Reach 1	18	141	244	3	33	31	2	23.4%	12.7%	66.7%
Reach 6	131	1,240	1,946	64	245	428	8	19.8%	22.0%	12.5%
Chi-square test result:								0.83	10.74	3.04
Critical Chi-square (df = 1; α = 0.05):								5.02	5.02	5.02

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error.

Table 9. Recovery distribution of disk tagged sockeye adults on the Chilko River system spawning grounds, by sex and tag application location, 1994.

Recovery location of disk tagged carcasses ^a													
Sex	Application location	Lower River		Middle River		Upper River		Sp. channel		North Lake		South Lake	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Male	Reach 1	3	9%	18	55%	7	21%	0	0%	5	15%	0	0%
	Reach 6	8	3%	125	50%	83	33%	5	2%	28	11%	1	0%
Female	Reach 1	1	3%	16	50%	5	16%	1	3%	9	28%	0	0%
	Reach 6	12	3%	235	54%	139	32%	10	2%	39	9%	3	1%

^a Section definitions: see Table 7.

Table 10. Proportion of the disk tag application sample recovered on the Chilko River system spawning grounds, by sex and 3 cm increments of nose-fork length, 1994. ^a

Nose-fork length (cm)	Disk tags applied ^b			Carcasses recovered with disk tags			Percent recovered		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
40-42.9	13	0	13	3	0	3	23.1%	-	23.1%
43-45.9	24	4	28	1	1	2	4.2%	25.0%	7.1%
46-48.9	15	4	19	1	2	3	6.7%	50.0%	15.8%
49-51.9	11	26	37	0	4	4	0.0%	15.4%	10.8%
52-54.9	63	303	366	10	63	73	15.9%	20.8%	19.9%
55-57.9	371	1,072	1,443	73	224	297	19.7%	20.9%	20.6%
58-60.9	634	659	1,293	124	143	267	19.6%	21.7%	20.6%
61-63.9	249	105	354	63	20	83	25.3%	19.0%	23.4%
64-66.9	46	25	71	8	6	14	17.4%	24.0%	19.7%
67-69.9	11	3	14	0	1	1	0.0%	33.3%	7.1%
Kolmogorov-Smirnov 2-sample Dmax:							0.03	0.03	-
K.S. Critical Value ($\alpha = 0.05$):							0.09	0.07	-

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error; jacks and jills included.

Table 11. Sex composition of Chilko River system sockeye adults in the disk tag application and spawning ground recovery samples, 1994. ^a

Sex	Application sample, by recovery status ^b				Recovery sample, by mark status			
	Sample size	Recovered	Not recovered	Total	Sample size	Marked	Unmarked	Total
Male	1,381	37.7%	38.9%	38.7%	41,963	37.7%	41.2%	41.2%
Female	2,190	62.3%	61.1%	61.3%	59,829	62.3%	58.8%	58.8%
Chi-Square Test Result:				0.31	3.62			
Critical Chi-Square (df = 1; $\alpha = 0.05$):				3.84	3.84			

^a Excludes carcasses recovered in the spawning channel.

^b Corrected for sex identification error.

concluded, therefore, that the recovery sample was relatively unbiased with respect to sex.

Stress

Potential bias resulting from handling and tagging stress was assessed in two ways. First, three tests were performed to determine whether specific tags should be excluded from the application sample. The results of these tests were reported on pages 10-11; no disk tags were removed from the samples. Second, two tests were performed as general indicators of a stress problem: a) spawning success was compared between tagged (97.7%) and untagged (97.1%) females. The input data for this test of independence (number of recoveries which were 0%, 50% and 100% spawned) were collapsed into

two groups because of the low number of expected recoveries in the 50% group. No significant difference ($P > 0.05$; chi-square) was noted; and b) the recovery sample was partitioned into those recovered above and below the Lingfield Creek tagging site and the disk tag incidence and female spawning success were compared in each. Tag incidence below the tagging site (0.79%) was not significantly different ($P > 0.05$; chi-square) than in the middle (0.85%) and upper (0.79%) river in either sex (Table 7), nor was spawning success (97.1% below and 96.0% above). Further, no tagged fish were observed drifting downstream at Henry's Bridge, and only 1 (0.002%) of the 47,485 observed immigrants had been previously tagged. We concluded, therefore, that handling and tagging stress did not introduce substantial bias to this study.

Table 12. Escapement estimates and 95% confidence limits, by age and sex, for Chilko River system adult and jack sockeye salmon, 1994. The symbol * indicates the final study area escapement estimates.

Stratification type	Estimator	Sex	Escapement at age ^a					Total	95% confidence limits on total escapement	
			3 ₂	4 ₂	4 ₃	5 ₂	5 ₃		Lower	Upper
Pooled	Petersen	Male	-	-	-	-	-	187,684 *	166,868	208,500
		Female	-	-	-	-	-	261,131 *	238,406	283,855
	Total	-	-	-	-	-	448,814 *	417,997	479,632	
	Jack	-	-	-	-	-	1,477 *	661	2,294	
Spatial ^b	Schaefer	Male	-	-	-	-	-	188,034	-	-
		Female	-	-	-	-	-	263,463	-	-
	Darroch	Male	-	-	-	-	-	d	-	-
		Female	-	-	-	-	-	318,475	250,153	386,797
Temporal ^c	Schaefer	Male	-	-	-	-	-	187,666	-	-
		Female	-	-	-	-	-	264,517	-	-
	Darroch	Male	-	-	-	-	-	188,598	165,448	211,748
		Female	-	-	-	-	-	274,770	247,265	302,275

^a. Excludes 50 females killed for fecundity samples. Age-specific estimates are unavailable; see Discussion.

^b. A 2x4 matrix: Camp and Lingfield Creek application; lower, middle and upper river and lake recovery.

^c. A 5x3 matrix: 22-27 Aug, 28-31 Aug, 1-2 Sep, 3-6 Sep, 7-20 Sep application; 5-28 Sep, 29 Sep to 1 Oct, 2-22 Oct recovery.

^d. Estimator failed to converge.

SPAWNER POPULATION ESTIMATES

Study Area

Petersen Estimator: The pooled Petersen estimate was calculated for the river, north lake and south lake study area from the data presented in Table 1. Escapement was estimated for adult males, adult females and jacks, with adults delineated by a minimum 50 cm NF length. Escapement by age was not estimated because the age structure of the south lake population was significantly different from the north lake and river populations (Table 3). Without an independent estimate of the relative size of the lake and river populations, the age data could not be appropriately weighted to abundance. This issue is dealt with in greater detail in the Discussion.

The 1994 sockeye adult escapement to the Chilko River system study area was estimated at 448,814 with 95% confidence limits of $\pm 30,818$ (6.9%) (Table 12). The escapement of male and female adults was $187,684 \pm 20,816$ (11.1%) and $261,131 \pm 22,725$ (8.7%), respectively. The jack

escapement was estimated at 1,477, with 95% confidence limits of ± 816 (55.2%).

Stratified Estimators: Because both spatial and temporal biases were identified in the sampling data, stratified estimates were calculated using the Schaefer and Darroch estimators (Table 12). Spatially, the data were initially stratified into two application (Table 8) and five recovery (Table 7) locations; however, the lake was collapsed into a single stratum because insufficient tags were recovered in the south end. Temporally, the data were initially stratified into five periods, each with an approximately equal number of tags applied (Table 6c), and five periods, each with an approximately equal number of carcasses recovered (Table 4c); however, the two initial and final recovery strata were collapsed into single strata because insufficient tags were recovered early and late in the study.

The stratified estimates of the male and female escapements ranged from 0% to +1% and +1% to +22% of the Petersen estimates, respectively. Only the spatially stratified Darroch

estimate fell outside the 95% confidence limits of the pooled Petersens. The confidence limits of the Darroch and Petersen estimates overlapped, however, and the Petersen estimate fell within the confidence limits of the Darroch estimate. The pooled Petersen, therefore, was accepted as the most appropriate population estimator.

Spawning Channel

The escapement to the Chilko River spawning channel was not included in the above study area estimate. The 1994 spawning channel escapement, estimated from a complete census, totalled 791 adult males, 1,139 adult females and 17 jacks (Appendix 5d). The 1994 total escapement to the Chilko River, spawning channel, and north and south ends of Chilko Lake is provided in Appendix 1a.

DISCUSSION

MARK-RECAPTURE ASSUMPTIONS

The Petersen mark-recapture technique is based on the principle that, by tagging a random sample of fish, permitting them to redistribute through the population, and by obtaining a second random sample of tagged and untagged individuals, the number of fish in the population can be estimated with known precision. Even a very precise estimate, however, can be inaccurate. The accuracy of an escapement estimate depends on how well the assumptions underlying the technique have been addressed. These assumptions have been described in various forms by Ricker (1975), Otis *et al.* (1978), Eames *et al.* (1981) and Seber (1982) and are restated below in the context of the current study.

Population Closure

A closed population is one where the number of animals does not change during the study. In spawning salmon populations, this implies that there is neither recruitment nor immigration, and that death and emigration affect tagged and untagged fish equally. Functionally, closure also implies that all components of the population will be vulnerable to either capture or recapture. The Chilko study addressed the closure assumption through temporal and spatial design elements. Temporally, the study was intended to encompass virtually the entire period of immigration,

spawning and die-off. This objective was not achieved, however, because tagging did not begin until three days after significant numbers of fish were first observed at Henry's Bridge (Fig. 5), and the lake recovery surveys began after the start of die-off (Appendix 5a,5b). Consequently, a component of the early migrant group may not have been vulnerable to either capture or recapture. While this would violate the closure assumption, we do not believe the violation was severe because: a) this component of the run was relatively small (less than 10% of the annual bridge count); and b) some of these fish would have been vulnerable to subsequent tagging in the upper river and to the carcass recovery surveys. For example, a significant proportion of the fish tagged during August 22-26 died late enough to be recovered as carcasses. Regardless, this issue should be addressed in future studies by expanding the duration of the surveys.

Spatially, the study was restricted to the terminal spawning areas and efforts were made to ensure that all fish would be vulnerable to the application or recovery surveys; however, emigration from the study area was a concern in two respects. First, fish bound for the spawning channel were vulnerable to tag application at Lingfield Creek but were recovered at a much higher rate than other study area fish because the channel was censused. While not strictly a violation of the closure assumption, this could bias the population estimate if the vulnerability of these fish to initial capture differed from other study area fish. Consequently, fish recovered during the census of the channel were excluded from the study population. Second, a small component of the population spawned in the Chilko River below Lingfield Creek. This group presents a concern because it may have been nonvulnerable to tag application (unless the fish dropped back from upstream areas) and these spawning areas were surveyed less intensively. For example, the survey frequency between the tagging site and Henry's Bridge was less than one-third that of the upstream areas, and the section below Henry's Bridge was not surveyed at all. This is important because fish stressed during tagging may have dropped back and died below the tagging site. While this would have violated the closure assumption, we do not view the violation as a serious one because spawning density in these areas is known from previous years' surveys to be low, and the tag rate in the fish recov-

ered in the upper part of this area during the current study was similar to that in upstream recoveries. Regardless, this issue should be addressed in future studies by expanding the extent and frequency of the lower river surveys.

Identification of Tag Status

The failure to correctly identify the tag status of a carcass is common in mark-recapture studies. It generally results from surveyor inexperience, fatigue, or from assigning a higher priority to the speed of carcass processing than to the thoroughness of carcass examination. The latter especially applies to major stocks such as the Chilko where the number of carcasses processed each day can be large (greater than 2,500 carcasses per person). If uncorrected, this type of error results in an underestimate of the proportion of tags in the population and an overestimate of escapement. In the current study, the proportion of the tags missed by the initial survey was evaluated by resurveying about 20% of the carcasses in previously surveyed areas; the proportion of the tags missed was 8.8% or 72 tags. Because this proportion was large relative to other 1994 studies (Schubert 1997), three procedural changes are recommended to reduce the missed tag rate in future studies: staff training should reemphasize the importance of carefully examining each carcass; the crew chief, through more frequent resurveys, should provide immediate feedback to staff who are missing tags; and the crew size should be increased during the peak recovery period, thereby reducing the daily number of carcasses processed by each individual. Further, the relationship between the daily number of carcasses processed by an individual and the missed tag rate should be investigated and, if appropriate, a maximum daily carcass processing level should be established.

We have four concerns with the design of the resurvey sample and the analytic treatment of the resurvey data. First, the resurveys were relatively unsystematic, i.e. they were less frequent than the initial surveys and did not representatively sample all spatial and temporal components of the run. For example, resurveys were less frequent in the lower river relative to the upper river, the north lake shoreline was resurveyed only once and the south lake shoreline was not resurveyed at all, and the proportion of the carcasses which were resurveyed was higher la-

ter in the study for both sexes and was lower during the peak of die-off in males. Unsystematic resurveys could introduce error in the population estimate if the missed tag rate was not uniform during the study, e.g. if the proportion of tags missed was related to the daily number of fish processed, to surveyor fatigue, or to the physical characteristics of the survey area. While stratification is an option, it was not considered in the current study because sample size was inadequate in several spatial and temporal cells. This issue should be addressed in future studies by a more representative resurvey. Second, tagged fish could be injected into the population between the initial survey and the resurvey of an area in two ways: a) rising and falling river levels (or lake winds) between the two surveys could inject new tags into the resurvey population; and b) animals could inject new tags by dragging ashore carcasses which later could not be identified as predator kills. Such actions would result in an overestimate of the proportion of tags in the population and an underestimate of the escapement. This type of error was unlikely in the current study because flows were stable and predator activity was generally minor; however, this issue is potentially a serious one which should be addressed in the design of future studies. Such error could be controlled by reducing the elapsed time between the two surveys; it could be eliminated by applying an unambiguous mark (e.g. abdominal incision or chopping the fish in two) to processed carcasses. Third, as with the sex identification error correction, there is no variance estimator for the resurvey sampling stage. Consequently, the precision of the population estimate was overstated. This should be addressed in the analytic design of future studies. Fourth, if estimator variance is to be minimized, simulation studies are required to determine the optimal allocation of effort between the initial and resurvey sampling stages.

Tag Loss

The undetected loss of tags between tag application and recovery would result in an underestimate of the proportion of the population with tags and an overestimate of escapement. Tag loss can result from poor tag application technique, tangling of the tag in the net after release, or the fighting which is common among males during spawning. It can be easily evaluated (although with an incremental labour cost) by apply-

ing a secondary tag, or a mark such as an opercular punch or fin clip, in addition to the primary tag. Tag loss in the current study could not be assessed because secondary marks were not used. A 1989 tag loss study, however, reported an average 3.5% (range 0% to 9.7%) loss of the primary tag in seven Fraser river sockeye stocks (DFO, unpublished). Studies of Fraser River chinook (Schubert *et al.* 1994a) and coho (Schubert *et al.* 1994b) also reported levels of tag loss which varied annually within about the same range. If tag loss in the current study was similar to that reported in the 1989 studies, the 1994 escapement would have been overestimated by approximately 15,000 sockeye (range 0 to 43,000). Clearly, tag loss could introduce a substantial bias in the population estimate and its assessment should be an integral part of all future mark-recapture studies. We note, however, that a positive bias of the same relative magnitude would also have occurred in past years because tag loss was not evaluated by any previous mark-recapture study.

Tagging Effects

Tagging can influence subsequent catchability if, for example, a tagged fish becomes more vulnerable to a fishery, to technicians or to predators. This type of tagging effect had little impact on the current study because: there were no fisheries upstream from the tagging site; the capture net was the only net used in the river, and few previously tagged fish were recaptured; the technicians were trained to recover carcasses independent of their tag status; and, although there was no indication that predators differentially removed tagged fish, predator recoveries were excluded from the sample.

The capture, holding and tagging of fish can be a stressful process. Two potentially serious tagging effects which can be induced by capture and tagging stress are: a) behavioral changes which violate the assumption of constant and equal probability of capture and recapture; and b) acute or short-term mortality, which violates the closure assumption and causes an underestimate of the proportion of tags in the population and an overestimate of escapement. The impact of low level or sub-acute stress may be trivial, or it may be manifested in subtle behavioral changes which influence subsequent catchability but which do not affect the ability of the fish to

spawn successfully. If the stress is particularly severe, some individuals may die within a few days of release, and others may drift downstream and die outside the study area.

In the current study, we attempted to minimize handling stress by ensuring that the capture and tagging processes were as stress-free as possible. This was done by selecting a tagging site where fast water would not stress the fish being held for tagging, by minimizing the holding time, and by applying tags sufficiently near the main river spawning grounds to minimize stress induced mortality while at the same time permitting the complete mixing of tagged and untagged fish. Regardless, there are three types of stress-related tagging effects which are of potential concern in the current study. First, sub-acute stresses could affect the behaviour of a fish in a way which would change its subsequent catchability. This type of stress could be expressed in three ways: a) the ability of stress-weakened fish to hold position in faster currents could be impaired, forcing them to spawn in slower flowing water along the river periphery. This could increase the probability that the fish would wash ashore and would result in a higher recovery rate among the stressed group; b) sub-acute stress may impair the ability of a fish to spawn successfully, resulting in a measurable reduction in spawning success; and c) the time span between release and death could be somewhat shorter among the stressed group. Our statistical tests (described earlier), however, did not detect any of these sub-acute stress effects in 1994 (Table 13). We also compared the arrival and die-off curves of the tagged component of the population with those of the entire population, as represented by the arrival pattern at Henry's Bridge and the total die-off (Fig. 5). There was no indication that sub-acute stress impaired the random mixing of tagged and untagged fish by reducing the life span of the former.

Second, a severe acute stress could result in death, immediately or within a few days of tagging. This type of stress could be expressed in two ways: a) the ability of seriously stressed fish to move beyond the tagging site could be impaired, resulting in a higher probability of recovery downstream and a lower level of spawning success. In an extreme case, such fish could be flushed from the system; and b) the time span between release and death could be consider-

ably shorter among the stressed group. Our statistical tests between fish recovered upstream and downstream from the tagging site showed no evidence of these acute stress effects in 1994. Although the observation of one previously tagged moving upstream past Henry's Bridge demonstrated that some tagged fish dropped below the tagging site, we were unable to determine if this was a tagging effect or if it represented the normal intrasystem movement of spawning sockeye.

Third, both sub-acute and acute stresses could differentially impact specific components of the study population. The 1994 Chilko River system study was designed to estimate the escapement of three major stocks, the river, north lake and south lake populations. Such system-wide tagging programs can be more susceptible to the delayed mortality which can result from capture and tagging stress because one component of the population, in this case the south lake spawners, must travel considerably greater distances after tagging than the others and may be unfit to do so. Stress, therefore, may play a more prominent role in determining the subsequent catchability of this component of the population than it does for the river spawner which have a comparatively shorter distance to travel to the spawning grounds. For example, Simpson (1984) reported that the severity of this type of bias increased with distance between the tagging site and the spawning grounds in some sockeye stocks. In the current study, tag incidence among the lake spawners was indeed lower than among the river spawners (Table 7); however, we were unable to determine whether this reflected a stress-induced reduction in the survival of the tagged fish or a violation of the assumption of equal probability of capture (discussed later). Both could introduce substantial biases into the population estimate, although the effect of the latter would be mediated by the lower probable recovery rate in the lake. This is discussed in the sampling selectivity section.

In summary, none of our tests demonstrated a serious concern with stress-induced tagging effects in the 1994 Chilko study. We were unable to discount the possibility that sub-acute and acute stresses did not bias the population estimate, however, and we recommend several design changes to permit such an assessment in the future: a) to permit the assessment of the

relative importance of tagging effects and sampling selectivity, tag application should begin earlier, and the river and lake should be surveyed with equal frequency; b) to evaluate the Chilko stock's susceptibility to stress and the potential impact of sub-acute stress on the study results, high and low stress tag application techniques should be developed; c) to permit a more thorough assessment of acute tagging effects, surveys of the river below the tagging site should begin immediately after the start of tagging, and the frequency and extent of these surveys should be increased; and d) a radio tagging study should be implemented to better assess acute tagging effects and to evaluate the role of stress in the observed low tag incidence in the lake populations.

Sampling Selectivity

The assumption of equal probability of capture and simple random sampling is violated in virtually all mark-recapture studies and is generally considered to be an unattainable ideal (Otis *et al.* 1978). This condition can be relaxed to some extent, however, without introducing bias in the population estimate. Junge (1963) showed that selectivity can exist in both samples without introducing a bias in the population estimate if the sources of selectivity are independent, and if the selectivity in the recovery sample is independent of tag status. When nonrepresentative sampling occurs, it can be at least partially addressed by using a stratified population estimator.

The design of the current study attempted to address this assumption by making both tag application and recovery as representative as possible. Tags were applied in proportion to the daily index of abundance from Henry's Bridge and by using a gear (beach seine net) known to minimize selectivity; complete spawning ground surveys were scheduled on a cycle of a fixed number of days regardless of carcass abundance. Areas where this study design could not be fully implemented are discussed below.

The linear regressions of tagged and untagged Chilko sockeye showed irregular patterns of residuals without a time trend in the recovery rates. This indicates that the assumption of equal probability of capture and simple random sampling necessary for an unbiased Petersen

Table 13. Bias profile for the 1994 Chilko River system sockeye escapement estimation study. ^a

Sample	Bias type	Test of	Between	Test result
Application	Temporal	Tag incidence:	Equal recovery periods	No bias
			Equal Recovery effort	No bias
			Equal numbers of recoveries	No bias
	Spatial	Tag incidence:	3 river/2 lake recovery areas	Higher tag incidence in river
			3 river recovery areas	Higher tag incidence in upper river
			2 lake recovery areas	No bias
	Fish sex	Sex ratio:	Marked/unmarked recoveries	No bias
	Stress	Recovery rate: Recovery of a tag within 5-days of rel:	Ventilated/nonventilated releases	No bias
			Tagged/untagged recoveries	No bias
			Above and below tag site	No bias
Above and below tag site			No bias	
Tag incidence:			No bias	
Recovery	Statistical	Minimum recovery of 5 tags:	-	No bias
	Temporal	Recovery rate:	Equal application periods	High late recovery in females/jacks
			Equal application effort	High late recovery in females/jacks
			Equal numbers applied	High late recovery in females/jacks
	Spatial	Recovery rate:	2 application sites	High recovery, Lingfield females
	Fish size	Size-frequency distrib:	Recovered/nonrecovered tags	No bias
Fish sex	Sex ratio:	Recovered/nonrecovered tags	No bias	

^a A "no bias" test result indicates that bias was not detected; undetected bias may be present.

population estimate was not met. We could not definitively test sample representativeness, however, because the true population parameters were not known. Instead, we constructed a bias profile by examining the samples for five potential biases, temporal, spatial, fish size, fish sex and stress, as indicators of weaknesses in the study design (Table 13). Three biases were detected in the application and recovery samples: a) a spatial recovery bias toward females tagged in the upper river. This was not surprising because the objective of tagging in the upper river was not to apply a representative sample but, rather, to tag fish which had migrated past Lingfield Creek before the start of the study. This objective was at least partially achieved; a higher

proportion of these fish were recovered in the lake (Table 9), a population which is known to have migrated through the river in the early part of the run (Table 5); b) a temporal recovery bias toward late female spawners. This bias was specific to the river recoveries; i.e. it was not detected when the lake recoveries were analyzed separately; and c) a spatial application bias toward river spawners. The low tag incidence in the lake (0.43%) versus the river (0.79%) spawners may have resulted from sub-acute stress, the late start of tagging, or an inherently low vulnerability of lake fish to capture in the river. We also note that small schools of up to 30 sockeye were observed migrating into the lake as early as August 20. Although the total number is unknown,

Table 14. Population estimation error, at simulated lake population mark incidences ranging from 0.25% to 1.00% and recovery rates ranging from 5% to 20%, for two cases: lake and river populations of equal size; and a lake population which is small relative to the river population.

Simulated river statistics		Simulated lake statistics		% bias when true population sizes are:	
Mark incidence	Recovery rate	Mark incidence	Recovery rate	River = 250,000 Lake = 250,000	River = 450,000 Lake = 50,000
1.00%	20.0%	1.00%	20.0%	0.0%	0.0%
1.00%	20.0%	1.00%	15.0%	0.0%	0.0%
1.00%	20.0%	1.00%	10.0%	0.0%	0.0%
1.00%	20.0%	1.00%	5.0%	0.0%	0.0%
1.00%	20.0%	0.75%	20.0%	0.0%	0.0%
1.00%	20.0%	0.75%	15.0%	-2.1%	-0.7%
1.00%	20.0%	0.75%	10.0%	-4.7%	-1.3%
1.00%	20.0%	0.75%	5.0%	-8.0%	-1.9%
1.00%	20.0%	0.50%	20.0%	0.0%	0.0%
1.00%	20.0%	0.50%	15.0%	-4.7%	-1.3%
1.00%	20.0%	0.50%	10.0%	-10.1%	-2.5%
1.00%	20.0%	0.50%	5.0%	-16.8%	-3.8%
1.00%	20.0%	0.25%	20.0%	0.0%	0.0%
1.00%	20.0%	0.25%	15.0%	-8.0%	-1.9%
1.00%	20.0%	0.25%	10.0%	-16.8%	-3.8%
1.00%	20.0%	0.25%	5.0%	-26.6%	-5.7%

these fish would have contributed to the lower tag incidence in the lake.

We spatially and temporally stratified the study data to address the above assumption violations. Because the variations among the stratified and pooled estimates were small and the stratified estimates were generally within the 95% confidence intervals of the pooled Petersen estimate, we concluded that the assumption violations may not have been particularly severe and were unlikely to have introduced bias into the population estimate.

While there is no indication that the three biases discussed above introduced a serious bias into the population estimate, we are concerned that a combination of biases acting in concert with the unique attributes of the lake population had the potential to do so. Lake spawners were tagged at a much lower rate than river spawners, a possible reflection of stress-induced mortality or differential vulnerability to capture in the river resulting from either their earlier migration or some other unidentified be-

havioral characteristic. Although a lake recovery bias was not identified by our statistical tests, one may have been present because: a) the lake surveys did not begin until well after the start of die-off and were less than half as frequent as the river surveys; b) the carcasses were less likely to wash ashore along the rock cliffs of the south lake; and c) the prevailing winds tended to push the carcasses away from the only substantial beaches in the extreme south end of the lake. Because south lake carcasses probably floated for longer periods, their recovery rate would be lower because drifting carcasses were more difficult to see and were likely to decompose and sink before reaching shore. This possible combination of low vulnerability to both tag application and recovery would introduce bias in the system-wide escapement estimate; the possible nonvulnerability of the early component of the lake population to both samples is especially disturbing. To determine the probable direction and magnitude of this bias, we simulated the river and lake system under different scenarios of lake application and recovery bias and river and lake population sizes. The results of the simulation of

two relative stock sizes, where the river statistics were set at approximately the observed levels (1.00% tag incidence; 20% recovery rate) and the lake statistics were varied within the maximum probable range (0.25%-1.00% tag incidence; 5%-20% recovery rate), are presented in Table 14. Two general conclusions can be drawn from the simulations: a) this combination of sampling biases would result in an underestimate of the system-wide escapement; and b) a large bias would occur only if sampling selectivity was extreme and the lake population was large, i.e. equal to or larger than the river population. Because we were unable to determine if either of these conditions occurred in 1994, we recommend three study design changes to permit the assessment of this potential bias in future studies: a) live capture should begin as soon as sockeye are observed at Henry's Bridge, and application effort should be increased in the early component of the run; b) the frequency of the lake and river surveys should be approximately equal and the lake surveys should commence earlier; and c) methods should be developed to provide independent estimates of the relative abundance of the river and lake populations.

It is worth noting that the two most probable explanations for low tag incidence among lake spawners, stress-related mortality and sampling selectivity, would introduce opposite biases into the system-wide population estimate. If both were present, therefore, the net impact on the population estimate would be less than if either were present individually. Further, the direction and magnitude of potential biases in the Chilko system population estimate would not be expected to differ from recent years since system-wide mark-recapture studies have been conducted there since 1989.

AGE STRUCTURED ESCAPEMENT

The lake population had a number of attributes which made it distinct from the river population. First, lake spawners tended to migrate through the Chilko River, spawn and die earlier than river spawners. Lake spawners constituted about 25% of the August migrants but only 5% of the September migrants, and the die-off was complete about a week earlier than in the river. A similar observation was reported for the 1971-1972 escapement by Saito and Woodey (MS 1973). Second, fish size and scale circuli counts

at age were slightly smaller in the south lake sample. The differences were significant ($P < 0.001$; ANOVA), however, only in age 4₂ males and females. The proportion of jacks in the recovery sample was also larger in the south lake. These observations may reflect either the true attributes of the population, or sampling bias. In rivers, the probability that the current will wash a carcasses out of the study area is greater among smaller fish. For example, Starr and Schubert (1990) reported lower recovery rates among smaller chinook in a six year study on the Harrison River, and Schubert (1993) reported an order of magnitude difference in recovery rate between adult and jack chinook in the Squamish River system. This would introduce a positive bias in the estimated body size in a sample. In lakes, however, size is unlikely to have influenced the probability of recovery because size-related environmental factors were not present. Because the lake sample may be relatively bias free, the apparent differences in body size, circuli counts and proportion jacks may reflect a sampling artifact. We acknowledge, however, that this effect would have to be large to produce the observed results. Third, the age structure of the south lake population was distinct from those in the river and north lake in that the proportion of age 4₃ fish was larger in both the adult and jack samples. Age 4₃ fish comprised 90% of the south lake sample but only 10% of the river sample. This difference in age structure compromised our ability to estimate escapement at age because the relative size of the two populations was unknown. We investigated other methods to develop a weighted age-specific population estimate, e.g. weighting the samples by the numbers of carcasses recovered, the sample size, or the proportion of the run in the first peak observed at Henry's Bridge. We concluded, however, that the potential error in the rare age classes was sufficiently large to negate the use of an arbitrary weighting scheme. The estimation of escapement by age for these populations is contingent upon the development of methods to provide independent estimates of the abundance of the south lake, north lake and river populations.

SPAWNING CHANNEL OPERATION

The spawning channel population was atypical of both the river and lake populations in two respects: a) the average elapsed time between disk tag release and channel recovery was 1-2

weeks less than for the river and lake recoveries (Table 2), and elapsed times of less than ten days were unique to the channel; and b) spawning success averaged less than half that of river and lake recoveries, and was especially poor among the early recoveries. These observations indicate that the channel fish were exposed to a stress additional to that experienced by the general population. There are two explanations. First, stressed fish are more likely to seek out protected, slack water areas such as in the channel. This would not explain, however, why a similar phenomena was not observed in the riverine slack water areas. Second, the channel itself could have been the source of stress. The channel operated from the start of the migration and probably was loaded more from the early part of the run. Early run fish have two characteristics which make them more susceptible to channel stress: a) early migrants in general tended to spawn less successfully (Table 2); and b) lake spawners comprised a much higher proportion of the early migrants (Table 5). Because the channel operated from the start of the run and did not provide a means for fish to return to the river, and because actively migrating, shore oriented lake spawners were more likely to enter the channel, the channel population may have included a substantial number of lake fish which were unsuited to spawning in a riverine environment. To avoid this problem in the future, we recommend that channel loading be delayed at least until September 10 to permit lake fish to clear the river.

RECOMMENDATIONS

1. The resurvey of carcass recovery areas is an important component of a mark-recapture study because, for a number of reasons, errors can be made in the identification of disk tags during the initial survey. The following changes are recommended to improve the resurvey component of this study:

- Staff training must emphasize the importance of thoroughly examining each carcass for a disk tag;
- Crew chiefs should resurvey the recovery areas more frequently, and provide immediate feedback to crew members who miss disk tags;
- The relationship between the daily number of carcasses processed by an individual and

the proportion of the disk tags which were missed should be investigated and, if appropriate, a maximum daily carcass processing level should be established. This will permit the adjustment of the crew size during the peak period of carcass recovery to ensure that the daily number of carcasses processed per individual remains below that limit;

- The resurvey should be made spatially and temporally more representative;
- The frequency of resurveys should be increased to avoid inter-survey periods of high water which could inject new carcasses into the resurvey area;
- Predator activity should be documented to determine the need to apply an unambiguous mark (e.g. abdominal incision or cutting the carcass in two) to all processed carcasses;
- The variance of the resurvey sampling stage should be incorporated into the variance of the population estimator;
- Simulation studies are required to determine the optimum allocation of effort between the initial and resurvey sampling stages.

2. Secondary tags or marks should be applied to sockeye released with disk tags to permit the assessment of disk tag loss. In 1995, we recommend that all disk tagged fish receive a sex-specific opercular punch as a secondary mark. Implicit in this recommendation is the need for improved staff training and feedback discussed under Recommendation No. 1; improved training and clear standards for what constitutes a releasable tag would also reduce actual tag loss.

3. The sub-acute and acute stresses which may result from the capture, handling and tagging of sockeye adults were identified as a potential concern in 1994. Five study design changes are recommended to assess the role of stress in the Chilko study and to remove the potentially confounding influence of stress effects from the evaluation of sampling selectivity:

- To permit the assessment of the relative importance of tagging effects and sampling selectivity, tag application should begin earlier, and the river and lake should be surveyed with equal frequency;
- To evaluate the Chilko stock's susceptibility to stress and the potential impact of sub-acute stress on the study results, low stress

tag application techniques should be developed and compared with current methods;

- To permit a more thorough assessment of acute tagging effects, surveys of the river below the tagging site should begin immediately after the start of tagging, and the frequency and extent of these surveys should be increased;
- A radio tagging study should be implemented to better assess acute tagging effects and to evaluate the role of stress in the observed low tag incidence in the lake populations;
- Consistent techniques should be developed to estimate spawning success in disk tagged versus untagged females.

4. Three study design changes, some of which are identical to those identified for stress assessment, are recommended to assess the sampling selectivity issues identified in the 1994 study:

- Live capture should begin as soon as sockeye are observed at Henry's Bridge, and application effort should be increased in the early component of the run;
- Lake survey effort should be increased, and the frequency of the lake and river surveys should be approximately equal;
- Lake surveys should begin at least two weeks earlier than the September 17 start date used in the current study;

5. The Chilko Lake population (especially the south lake population) is distinct from the river population in two important respects: the age and size structures are significantly different; and lake fish appear to enter the system earlier and spawn in different environments. Our ability to accurately estimate the age structured study area escapement and to identify sampling selectivity differences between the river and lake populations is constrained by our lack of knowledge concerning the relative size of the two populations. Consequently, we recommend the development of methods to provide independent estimates of the relative abundance of the river and lake populations.

6. The entry into the spawning channel by sockeye destined for Chilko Lake may contribute to the high prespawn mortality observed in 1994. To maximize channel usage by river sockeye, spawners should be excluded from the channel at

least until September 10 to permit lake sockeye to clear the river.

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Appendices

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Chilko River system (excluding Taseko River and Lake), 1938-1994.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
1938	10,870	32	5,403	5,435	94.6%	5,142
1939	2,000	635	515	850	98.0%	833
1940	356,760	4,204	183,664	153,892	100.0%	153,892
1941	367,506	0	183,091	184,415	97.0%	178,938
1942	30,080	0	15,040	15,040	98.0%	14,739
1943	10,474	733	3,478	6,263	96.5%	6,044
1944	194,276	194	98,886	95,196	95.0%	90,436
1945	176,936	313	87,967	88,656	86.5%	76,687
1946	60,169	359	30,980	28,830	90.9%	26,206
1947	54,931	4,999	21,094	28,838	98.6%	28,435
1948	671,025	403	277,737	392,885	92.8%	364,597
1949	58,310	63	24,056	34,191	96.6%	33,029
1950	26,447	9,139	9,815	7,493	87.5%	6,555
1951	118,110	17,994	41,982	58,134	99.0%	57,563
1952	490,065	4,480	224,256	261,329	89.4%	233,628
1953	201,245	554	91,350	109,341	86.4%	94,471
1954	37,743	3,447	12,459	21,837	97.3%	21,247
1955	132,146	10,979	40,578	80,589	94.1%	75,834
1956	647,768	862	260,525	386,381	95.4%	368,607
1957	140,765	2,301	54,952	83,512	99.5%	83,128
1958	137,081	16,977	49,600	70,504	99.9%	70,433
1959	471,162	8,102	189,677	273,383	99.8%	272,891
1960	426,607	61	179,209	247,337	99.0%	244,864
1961	40,315	1,214	15,515	23,586	63.8%	15,038
1962	92,467	14,754	28,212	49,501	85.1%	42,125
1963	1,002,252	4,021	454,959	543,272	10.5%	57,207
1964	238,601	329	103,777	134,495	97.8%	131,590
1965	39,902	4,567	12,294	23,041	90.3%	20,813
1966	226,702	17,083	94,921	114,698	93.8%	107,541
1967	176,337	1,622	72,563	102,152	88.1%	90,006
1968	414,446	584	173,238	240,624	75.6%	181,912
1969	76,518	5,616	28,491	42,411	60.2%	25,519
1970	145,049	9,661	63,483	71,905	70.8%	50,923
1971	186,589	18,193	61,760	106,636	91.3%	97,365
1972	564,465	1,815	225,935	336,715	98.7%	332,338
1973	61,707	6,032	24,786	30,889	97.9%	30,231
1974	142,595	32,569	36,653	73,373	96.9%	71,127
1975	275,698	31,067	93,352	151,279	88.4%	133,782
1976	387,467	3,077	152,245	232,145	98.4%	228,326
1977	56,782	5,452	21,507	29,823	68.4%	20,385
1978	159,174	12,332	60,865	85,977	99.5%	85,570
1979	272,694	14,303	90,701	167,690	88.2%	147,920
1980	498,826	1,067	182,219	315,540	92.9%	293,234
1981	36,149	1,609	13,019	21,521	93.7%	20,163
1982	253,551	3,973	102,549	147,029	96.9%	142,518
1983	386,571	3,738	156,877	225,956	94.6%	213,715
1984	580,664	485	287,029	293,150	96.6%	283,152
1985	88,120	16,145	36,652	35,323	99.0%	34,981

Continued

Appendix 1a. Sockeye jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Chilko River system (excluding Taseko River and Lake), 1938-1994, continued.

Year	Escapement				Percent spawning success	Effective females
	Total	Jacks	Males	Females		
1986	323,971	30,167	117,747	176,057	94.0%	165,504
1987	430,492	9,477	140,032	280,983	95.4%	268,029
1988	365,790	2,401	152,908	210,481	97.0%	204,117
1989	78,647	15,379	19,754	43,514	96.5%	42,008
1990	833,359	7,521	316,944	508,894	97.8%	497,763
1991	1,039,624	1,887	420,297	617,440	96.8%	597,537
1992	515,663	4,396	190,554	320,713	99.8%	319,959
1993	561,865	6,639	230,736	324,490	99.3%	322,298
1994	452,239	1,494	188,475	262,270	96.9%	254,061

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the south end of Chilko Lake, 1938-1989.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1939	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1940	n/r	n/r	15,000	n/r	n/r	n/r	n/r	n/r
1941	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1942	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1943	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1944	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1945	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1946	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1947	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1948	n/r	n/r	Present	n/r	n/r	n/r	n/r	n/r
1949	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1950	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1951	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1952	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1953	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1954	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1955	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1956	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1957	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1958	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1959	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1960	n/r	n/r	Present	n/r	n/r	n/r	n/r	n/r
1961	n/r	n/r	n/o	n/o	n/o	n/o	n/r	n/r
1962	n/r	n/r	n/o	n/o	n/o	n/o	n/r	n/r
1963	n/r	n/r	Present	n/r	n/r	n/r	n/r	n/r
1964	n/r	n/r	Present	n/r	n/r	n/r	n/r	n/r
1965	n/r	n/r	n/o	n/o	n/o	n/o	n/r	n/r
1966	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1967	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1968	n/r	n/r	Present	n/r	n/r	n/r	n/r	n/r
1969	n/r	n/r	n/o	n/o	n/o	n/o	n/r	n/r
1970	n/r	n/r	n/o	n/o	n/o	n/o	n/r	n/r
1971	n/r	Sep 05-Sep 15	12,323	1,120	4,033	7,170	93.8%	6,722
1972	n/r	Sep 05-Sep 15	2,132	249	670	1,213	100.0%	1,213
1973	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1974	n/r	Sep 08-Sep 15	14,464	14,001	84	379	88.9%	337
1975	n/r	Sep 09-Sep 15	55,144	10,252	11,667	33,225	95.6%	31,760
1976	n/r	Sep 18-Sep 22	23,156	518	5,821	16,817	99.6%	16,745
1977	n/r	Early Sep	2,460	669	836	955	57.9%	553
1978	n/r	Sep 10-Sep 15	7,339	3,899	596	2,844	100.0%	2,844
1979	n/r	Early Sep	32,400	8,933	10,000	13,467	97.0%	13,067
1980	n/r	Early Sep	30,168	221	12,782	17,165	99.9%	17,148
1981	n/r	Early Sep	240	60	100	80	100.0%	80
1982	n/r	Early/Mid Sep	11,288	1,613	3,112	6,563	99.7%	6,544
1983	n/r	Mid/Late Sep	55,061	1,448	18,187	35,426	99.8%	35,341
1984	n/r	Late Sep	127,696	135	63,104	64,457	98.0%	63,149
1985	n/r	Late Sep	2,000	1,460	279	261	100.0%	261

Continued

Appendix 1b. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the south end of Chilko Lake, 1938-1989, continued.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1986	n/r	Late Sep	13,574	1,541	4,823	7,210	95.2%	6,872
1987	n/r	Late Sep	188,789	7,375	51,058	130,356	98.7%	128,615
1988	n/r	Late Sep	110,608	1,887	37,279	71,442	99.6%	71,134
1989	n/r	Late Sep	20,128	9,899	2,310	7,919	100.0%	7,919
1990	n/r	n/r	n/r	n/r	n/r	n/r	n/r	n/r
1991	n/r	n/r	a	n/r	n/r	n/r	n/r	n/r
1992	n/r	n/r	a	n/r	n/r	n/r	n/r	n/r
1993	n/r	n/r	a	n/r	n/r	n/r	n/r	n/r
1994	n/r	n/r	a	n/r	n/r	n/r	n/r	n/r

^a Included in the Chilko River and north end of Chilko Lake estimate (Appendix 1b).

Appendix 1c. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Chilko River and the north end of Chilko Lake, 1938-1994.

Year	Arrival	Period of peak spawning	Escapement				Percent spawning success	Effective females
			Total	Jacks	Males	Females		
1938	Sep 01	Sep 16-Sep 20	10,870	32	5,403	5,435	94.6%	5,142
1939	Aug 30	Sep 27-Sep 30	2,000	635	515	850	98.0%	833
1940	Aug 15	Sep 17-Sep 26	341,760	4,204	183,664	153,892	100.0%	153,892
1941	Aug 14	Sep 20-Sep 30	367,506	0	183,091	184,415	97.0%	178,938
1942	Aug 12	Sep 20-Oct 01	30,080	0	15,040	15,040	98.0%	14,739
1943	Aug 21	Sep 24-Oct 01	10,474	733	3,478	6,263	96.5%	6,044
1944	n/r	Sep 20-Sep 30	194,276	194	98,886	95,196	95.0%	90,436
1945	Aug 09	Sep 20-Sep 30	176,936	313	87,967	88,656	86.5%	76,687
1946	Aug 19	Sep 24-Oct 01	60,169	359	30,980	28,830	90.9%	26,206
1947	Aug 18	Sep 24-Oct 01	54,931	4,999	21,094	28,838	98.6%	28,435
1948	Aug 12	Sep 24-Oct 01	671,025	403	277,737	392,885	92.8%	364,597
1949	Aug 11	Sep 20-Sep 25	58,310	63	24,056	34,191	96.6%	33,029
1950	Aug 18	Sep 22-Sep 25	26,447	9,139	9,815	7,493	87.5%	6,555
1951	Aug 08	Sep 20-Sep 23	118,110	17,994	41,982	58,134	99.0%	57,563
1952	Aug 11	Sep 21-Sep 23	490,065	4,480	224,256	261,329	89.4%	233,628
1953	Aug 10	Sep 16-Sep 18	201,245	554	91,350	109,341	86.4%	94,471
1954	Aug 24	Sep 23-Sep 25	37,743	3,447	12,459	21,837	97.3%	21,247
1955	Aug 21	Sep 23-Sep 25	132,146	10,979	40,578	80,589	94.1%	75,834
1956	Aug 12	Sep 22-Sep 25	647,768	862	260,525	386,381	95.4%	368,607
1957	Aug 16	Sep 24-Sep 26	140,765	2,301	54,952	83,512	99.5%	83,128
1958	Aug 23	Sep 27-Sep 30	137,081	16,977	49,600	70,504	99.9%	70,433
1959	Aug 17	Sep 29-Oct 01	471,162	8,102	189,677	273,383	99.8%	272,891
1960	Aug 17	Sep 26-Sep 30	426,607	61	179,209	247,337	99.0%	244,864
1961	Aug 13	Sep 24-Sep 27	40,315	1,214	15,515	23,586	63.8%	15,038
1962	Aug 20	Sep 25-Sep 28	92,467	14,754	28,212	49,501	85.1%	42,125
1963	Aug 08	Sep 16-Sep 20	1,002,252 ^a	4,021	454,959	543,272	10.5%	57,207
1964	Aug 22	Sep 29-Oct 03	238,601 ^a	329	103,777	134,495	97.8%	131,590
1965	Aug 19	Sep 24-Sep 27	39,902	4,567	12,294	23,041	90.3%	20,813
1966	Aug 21	Sep 22-Sep 26	226,702	17,083	94,921	114,698	93.8%	107,541
1967	Aug 15	Sep 24-Sep 27	176,337	1,622	72,563	102,152	88.1%	90,006
1968	Aug 12	Sep 23-Sep 27	414,446	584	173,238	240,624	75.6%	181,912
1969	Aug 15	Sep 19-Sep 22	76,518	5,616	28,491	42,411	60.2%	25,519
1970	Aug 12	Sep 22-Sep 24	145,049	9,661	63,483	71,905	70.8%	50,923
1971	Aug 08	Sep 24-Sep 28	174,266	17,073	57,727	99,466	91.1%	90,643
1972	Aug 12	Sep 24-Sep 28	562,333	1,566	225,265	335,502	98.7%	331,125
1973	Aug 18	Sep 21-Sep 22	61,707	6,032	24,786	30,889	97.9%	30,231
1974	Aug 25	Sep 22-Sep 29	128,131	18,568	36,569	72,994	97.0%	70,790
1975	n/r	Sep 22-Sep 27	220,554	20,815	81,685	118,054	86.4%	102,022
1976	Aug 12	Sep 22-Sep 29	364,311	2,559	146,424	215,328	98.3%	211,581
1977	Aug 19	Sep 18-Sep 23	54,322	4,783	20,671	28,868	68.7%	19,832
1978	Aug 22	Sep 26-Sep 29	151,835	8,433	60,269	83,133	99.5%	82,726
1979	n/r	Sep 16-Sep 20	240,294	5,370	80,701	154,223	87.4%	134,853
1980	n/r	Sep 20-Sep 29	468,658	846	169,437	298,375	92.5%	276,086
1981	n/r	Sep 21-Sep 27	35,909	1,549	12,919	21,441	93.7%	20,083
1982	Aug 21	Sep 18-Sep 23	242,263	2,360	99,437	140,466	96.8%	135,974
1983	Aug 12	Sep 15-Oct 02	331,510	2,290	138,690	190,530	93.6%	178,374
1984	Aug 06	Oct 04-Oct 10	452,968	350	223,925	228,693	96.2%	220,003
1985	Mid Aug	Oct 04-Oct 10	86,120	14,685	36,373	35,062	99.0%	34,720

a. Includes the south end of Chilko Lake.

Continued

Appendix 1c. Annual date of sockeye salmon arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Chilko River and the north end of Chilko Lake, 1938-1994, continued.

Year	Arrival	Period of peak spawning	Escapement			Percent spawning success	Effective females	
			Total	Jacks	Males			Females
1986	Mid Aug	Sep 28-Oct 04	310,397	28,626	112,924	168,847	94.0%	158,632
1987	Early Aug	Sep 28-Oct 08	241,703	2,102	88,974	150,627	92.6%	139,414
1988	Mid Aug	Sep 30-Oct 07	250,495	506	113,867	136,122	97.7%	132,983
1989	Aug 28	Sep 19-Sep 25	56,994	5,414	16,806	34,774	98.2%	34,089
1990	Mid Aug	Sep 21-Oct 01	823,385	7,481	313,426	502,478	97.9%	491,668
1991	n/r	n/r	1,019,116 ^a	1,874	412,105	605,137	97.1%	587,478
1992	n/r	n/r	508,582 ^a	4,346	188,199	316,037	99.9%	315,513
1993	Aug 17	Sep 25-Sep 30	556,466 ^a	6,621	228,520	321,325	99.4%	319,186
1994	Aug 07	Mid Sep	450,292 ^a	1,477	187,684	261,131	97.1%	253,558

^a. Includes the south end of Chilko Lake escapement.

Appendix 1d. Annual date of sockeye salmon of arrival and peak spawning, jack and adult escapement by sex, percent spawning success and the number of females which spawned effectively in the Chilko River spawning channel, 1988-1994.

Year	Arrival	Period of peak spawning	Escapement			Percent spawning success	Effective females	
			Total	Jacks	Males			Females
1988	Aug 19	Mid/Late Sep	4,687	8	1,762	2,917	69.9%	2,040
1989	Sep 08	Sep 19-Sep 24	1,525	66	638	821	98.2%	803
1990	Early Sep	Mid Sep	9,974	40	3,518	6,416	95.0%	6,095
1991	Late Aug	Mid Sep	20,508	13	8,192	12,303	81.8%	10,059
1992	Sep 06	Mid/Late Sep	7,081	50	2,355	4,676	95.1%	4,446
1993	Aug 24	Sep 17-Sep 25	5,399	18	2,216	3,165	98.3%	3,112
1994	Aug 30	Early Sep	1,947	17	791	1,139	36.7%	503

Appendix 2a. Daily sockeye counts, by 15-minute period, on the east side of the Chilko River at Henry's Bridge, 1994.

		Number of sockeye counted by time period																	
Date	From To:	8:30 8:45	9:00 9:15	9:30 9:45	10:00 10:15	10:30 10:45	11:00 11:15	11:30 11:45	12:00 12:15	12:30 12:45	13:00 13:15	13:30 13:45	14:00 14:15	14:30 14:45	15:00 15:15	15:30 15:45	16:00 16:15	16:30 16:45	Mean
5-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
6-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	1	-	-	-	0
8-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
10-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
12-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
13-Aug		-	-	-	-	-	0	0	0	2	0	0	1	1	2	-	-	-	1
14-Aug		-	-	-	-	-	-	-	-	-	2	0	0	1	3	2	3	0	1
15-Aug		-	-	-	-	-	0	2	4	7	4	5	2	0	0	-	-	-	3
16-Aug		-	-	-	-	-	2	0	0	0	1	0	1	0	2	-	-	-	1
17-Aug		-	-	-	-	-	54	19	17	14	5	51	10	10	8	-	-	-	21
18-Aug		-	-	-	5	4	1	1	6	7	9	14	43	3	12	15	56	17	14
19-Aug		-	-	-	81	87	242	15	27	31	42	17	147	9	9	20	122	52	64 ^a
20-Aug		-	-	-	40	98	39	37	153	168	65	123	105	77	65	60	51	43	80
21-Aug		47	83	59	115	232	204	209	-	287	52	112	33	413	185	22	-	-	147
22-Aug		36	55	59	21	50	8	2	-	36	180	180	208	322	87	81	-	-	95 ^a
23-Aug		91	87	283	253	147	57	95	-	10	4	40	149	36	31	64	-	-	96 ^a
24-Aug		34	13	2	5	9	38	58	-	18	17	87	19	0	10	-	-	-	22
25-Aug		42	142	55	69	28	46	36	-	70	26	23	38	9	11	35	-	-	45 ^a
26-Aug		14	23	23	8	15	117	130	-	13	24	76	70	105	51	76	-	-	53
27-Aug		81	130	267	148	135	175	189	-	35	134	83	100	151	90	128	-	-	132
28-Aug		19	53	154	240	37	119	150	-	318	247	134	20	144	516	166	-	-	166 ^a
29-Aug		80	375	309	122	135	101	48	-	25	31	135	42	37	57	20	-	-	108
30-Aug		46	172	115	166	576	152	212	-	363	136	609	59	111	546	533	-	-	271
31-Aug		101	487	507	668	913	481	738	-	507	725	751	759	851	620	402	-	-	608
1-Sep		277	326	101	105	9	34	258	-	370	362	316	424	686	607	518	-	-	314
2-Sep		225	360	356	364	141	128	5	-	177	248	235	273	297	159	78	-	-	218
3-Sep		21	81	101	76	72	79	240	-	252	204	209	152	148	73	133	-	-	132 ^a
4-Sep		54	32	21	50	19	59	46	-	72	41	79	52	23	22	17	-	-	42 ^a
5-Sep		34	44	19	161	75	114	93	-	76	62	73	44	38	72	80	-	-	70 ^a
6-Sep		101	134	115	172	106	207	180	-	124	118	46	63	120	52	192	-	-	124
7-Sep		50	64	33	18	42	38	12	-	26	38	74	42	128	49	86	-	-	50
8-Sep		7	11	18	19	35	15	16	-	13	31	39	20	27	29	43	-	-	23 ^b
9-Sep		22	48	45	45	38	31	33	-	62	77	36	31	56	60	74	-	-	47
10-Sep		19	27	64	73	183	69	42	-	49	27	22	22	39	40	41	-	-	51
11-Sep		18	76	35	78	91	101	139	-	47	51	17	60	27	54	39	-	-	60
12-Sep		74	100	57	69	36	35	163	-	44	13	52	73	92	77	38	-	-	66
13-Sep		37	107	154	102	219	111	136	-	154	112	77	27	57	77	55	-	-	102
14-Sep		3	29	25	27	51	39	110	-	61	30	75	29	42	42	62	-	-	45
15-Sep		10	41	15	17	21	16	30	-	10	27	26	27	11	9	31	-	-	21
16-Sep		22	22	25	13	18	20	19	-	32	11	10	8	17	16	13	-	-	18
17-Sep		25	12	32	15	20	4	8	-	9	13	18	8	10	8	9	-	-	14
18-Sep		10	17	15	18	7	4	15	-	11	11	20	5	17	4	22	-	-	13 ^a
19-Sep		17	7	13	3	5	38	47	-	45	32	11	16	11	5	2	-	-	18
20-Sep		6	7	6	9	8	9	18	-	24	18	14	7	16	27	5	-	-	12
21-Sep		6	1	3	15	11	9	6	-	18	21	2	8	3	5	2	-	-	8
22-Sep		7	5	1	9	4	11	5	-	9	19	10	3	8	4	13	-	-	8
23-Sep		11	4	5	7	7	11	2	-	6	22	12	5	5	4	7	-	-	8
24-Sep		3	3	1	0	5	2	9	-	6	11	3	13	6	1	5	-	-	5
25-Sep		19	16	10	7	10	11	19	-	3	16	6	1	3	4	0	-	-	9
Mean		46	89	86	88	95	64	76	-	77	69	82	67	87	79	80	-	-	65

^a Native gaff fishery disrupted the sockeye migration for part of the day.

^b Includes 1 sockeye with a disk tag.

Appendix 2b. Daily chinook counts, by 15-minute period, on the east side of the Chilko River at Henry's Bridge, 1994.

		Number of chinook counted by time period ^a																	
From	To:	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	Total
Date		8:45	9:15	9:45	10:15	10:45	11:15	11:45	12:15	12:45	13:15	13:45	14:15	14:45	15:15	15:45	16:15	16:45	
5-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
6-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
8-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
10-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11-Aug		-	-	-	-	-	1	0	0	0	0	0	0	0	0	-	-	-	1
12-Aug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
14-Aug		-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
15-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
16-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
17-Aug		-	-	-	-	-	0	0	0	0	0	0	0	0	0	-	-	-	0
18-Aug		-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Aug		-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 ^b
20-Aug		-	-	-	0	1	0	0	0	0	0	0	0	2	0	0	0	0	3
21-Aug		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
22-Aug		0	0	1	0	0	0	0	-	0	0	0	0	0	0	0	-	-	1 ^b
23-Aug		0	1	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	1 ^b
24-Aug		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
25-Aug		0	0	0	0	1	0	0	-	0	0	0	0	0	0	0	-	-	1 ^b
26-Aug		0	0	0	0	0	0	0	-	0	0	0	1	0	1	0	-	-	2
27-Aug		0	0	0	0	0	0	0	-	0	0	0	0	0	1	0	-	-	1
28-Aug		0	0	0	0	0	0	1	-	0	0	0	0	0	0	0	-	-	1 ^b
29-Aug		0	0	0	0	0	0	1	-	0	1	1	0	1	0	0	-	-	4
30-Aug		0	0	0	0	1	0	0	-	1	0	0	1	0	0	1	-	-	4
31-Aug		1	0	0	0	0	0	0	-	0	1	0	0	1	1	0	-	-	4
1-Sep		2	0	0	0	0	0	0	-	1	1	0	0	0	0	0	-	-	4
2-Sep		0	1	0	0	0	0	0	-	1	0	0	1	0	0	0	-	-	3
3-Sep		0	0	0	0	0	0	0	-	0	0	1	0	1	0	0	-	-	2 ^b
4-Sep		0	1	0	0	0	2	1	-	1	0	1	0	0	0	0	-	-	6 ^b
5-Sep		0	0	0	0	0	1	0	-	0	0	0	0	0	0	0	-	-	1 ^b
6-Sep		0	0	0	0	0	0	1	-	0	0	1	0	0	0	1	-	-	3
7-Sep		0	0	0	0	1	0	0	-	0	0	0	0	1	1	3	-	-	6
8-Sep		0	1	0	0	0	0	0	-	0	0	0	0	0	0	1	-	-	2
9-Sep		0	0	0	0	0	0	0	2	-	0	0	0	0	0	0	-	-	2
10-Sep		1	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	1
11-Sep		0	0	0	0	1	0	0	-	0	1	0	1	1	0	0	-	-	4
12-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	-	-	1
13-Sep		2	1	0	0	0	0	0	-	2	1	1	0	0	0	0	-	-	7
14-Sep		0	0	1	1	2	0	0	-	0	0	0	1	0	0	2	-	-	7
15-Sep		0	0	0	0	0	0	0	-	1	0	0	0	0	0	0	-	-	1
16-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	1	-	-	1
17-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
18-Sep		0	0	0	0	0	1	0	-	0	0	0	0	0	0	0	-	-	1 ^b
19-Sep		0	0	0	0	0	0	2	-	0	0	1	0	0	0	0	-	-	3
20-Sep		0	0	0	0	0	0	0	-	0	1	0	0	0	0	0	-	-	1
21-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
22-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
23-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
24-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
25-Sep		0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	-	-	0
Total		6	5	2	1	7	5	8	0	7	6	6	5	7	4	10	0	0	79

^a Chinook migrate offshore; therefore, counts may not reflect true abundance or migration pattern.

^a See footnote "a" in Appendix 2a.

Appendix 3. Daily application of disk tags, by location and sex (field estimate and correction for sex identification error), to sockeye salmon in the Chilko River, 1994. ^a

Date	Reach	Number of sets	Original field estimate of sex composition			Corrected for sex identification error ^c			Recaptures		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Aug. 22	1	9	38	60	3	35	63	3	0	0	0
Aug. 23	6	10	65	98	2	60	103	2	0	0	0
Aug. 24	6	6	26	53	2 ^b	24	55	2 ^b	0	0	0
Aug. 25	1	5	78	112	0	72	117	0	0	0	0
	6	1	31	22	0	27	25	0	0	1	0
Aug. 26	1	4	37	61	0	34	64	0	0	0	0
Aug. 27	6	5	45	36	2	41	39	2	0	0	0
Aug. 28	6	7	93	71	3 ^b	84	78	3 ^b	0	0	0
Aug. 29	6	4	81	97	3 ^b	73	104	3 ^b	0	0	0
Aug. 30	6	4	81	96	4 ^b	74	103	4 ^b	0	0	0
Aug. 31	6	3	125	169	6	115	179	6	0	0	0
Sept. 1	6	9	214	325	7	195	339	7	0	0	0
Sept. 2	6	7	141	188	3 ^b	128	198	3 ^b	0	0	0
Sept. 3	6	5	27	49	2	25	51	2	0	0	0
Sept. 4	6	9	67	110	3 ^b	61	114	3 ^b	0	0	0
Sept. 5	6	5	42	47	2	39	50	2	0	0	0
Sept. 6	6	4	44	58	3 ^b	40	62	3 ^b	0	0	0
Sept. 7	6	5	51	89	1	47	93	1	0	0	0
Sept. 8	6	7	24	34	0	22	36	0	0	1	0
Sept. 9	6	2	11	13	1	10	14	1	0	0	0
Sept. 10	6	4	19	38	1 ^b	17	40	1 ^b	0	0	0
Sept. 11	6	5	36	47	8 ^b	33	50	8 ^b	0	0	0
Sept. 12	6	3	38	34	0	35	37	0	0	1	0
Sept. 13	6	5	30	43	2	28	45	2	0	0	0
Sept. 14	6	6	39	52	6	36	55	6	0	1	0
Sept. 15	6	6	18	30	2	16	32	2	0	0	0
Sept. 16	6	4	2	21	1	2	21	1	0	0	0
Sept. 17	6	1	0	5	0	0	5	0	0	0	0
Sept. 18	6	1	2	1	0	2	1	0	0	0	0
Sept. 19	6	0	0	0	0	0	0	0	0	0	0
Sept. 20	6	3	7	16	0	6	17	0	0	0	0
Total	1	18	153	233	3	141	244	3	0	0	0
	6	131	1,359	1,842	64	1,240	1,946	64	0	4	0
Total		149	1,512	2,075	67	1,381	2,190	67	0	4	0

^a See Methods for sex identification error correction procedure.

^b Includes females (jills)(11 in total).

^c Excludes 5 male and 11 female disk tagged sockeye recovered in the spawning channel.

Appendix 4a. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among adult male sockeye examined at tag application in the Chilko River, 1994. ^a

Date	Number of adult males examined	Net marks		Lamprey marks		Hook marks		<i>F. columnaris</i>	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
Aug. 22	38	19	50.0%	3	7.9%	1	2.6%	0	0.0%
Aug. 23	65	31	47.7%	1	1.5%	0	0.0%	0	0.0%
Aug. 24	26	10	38.5%	0	0.0%	1	3.8%	0	0.0%
Aug. 25	109	28	25.7%	4	3.7%	11	10.1%	0	0.0%
Aug. 26	37	9	24.3%	4	10.8%	6	16.2%	0	0.0%
Aug. 27	45	13	28.9%	3	6.7%	3	6.7%	0	0.0%
Aug. 28	93	17	18.3%	11	11.8%	11	11.8%	1	1.1%
Aug. 29	81	18	22.2%	7	8.6%	4	4.9%	1	1.2%
Aug. 30	81	24	29.6%	7	8.6%	11	13.6%	0	0.0%
Aug. 31	125	37	29.6%	9	7.2%	10	8.0%	0	0.0%
Sept. 1	214	51	23.8%	12	5.6%	19	8.9%	2	0.9%
Sept. 2	141	41	29.1%	10	7.1%	8	5.7%	2	1.4%
Sept. 3	27	10	37.0%	0	0.0%	0	0.0%	5	18.5%
Sept. 4	67	15	22.4%	2	3.0%	6	9.0%	13	19.4%
Sept. 5	42	15	35.7%	0	0.0%	2	4.8%	3	7.1%
Sept. 6	44	15	34.1%	4	9.1%	1	2.3%	4	9.1%
Sept. 7	51	13	25.5%	5	9.8%	5	9.8%	6	11.8%
Sept. 8	24	9	37.5%	2	8.3%	0	0.0%	2	8.3%
Sept. 9	11	3	27.3%	1	9.1%	1	9.1%	2	18.2%
Sept. 10	19	3	15.8%	2	10.5%	0	0.0%	0	0.0%
Sept. 11	36	6	16.7%	1	2.8%	1	2.8%	0	0.0%
Sept. 12	38	6	15.8%	1	2.6%	1	2.6%	1	2.6%
Sept. 13	30	0	0.0%	0	0.0%	1	3.3%	2	6.7%
Sept. 14	39	3	7.7%	1	2.6%	2	5.1%	1	2.6%
Sept. 15	18	5	27.8%	0	0.0%	1	5.6%	0	0.0%
Sept. 16	2	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 17	0	0	-	0	-	0	-	0	-
Sept. 18	2	0	0.0%	0	0.0%	1	50.0%	0	0.0%
Sept. 19	0	0	-	0	-	0	-	0	-
Sept. 20	7	0	0.0%	1	14.3%	0	0.0%	0	0.0%
Total	1,512	401	26.5%	91	6.0%	107	7.1%	45	3.0%

^a Not corrected for sex identification error.

Appendix 4b. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among female sockeye examined at tag application in the Chilko River, 1994. ^a

Date	Number of females examined	Net marks		Lamprey marks		Hook marks		<i>F. columnaris</i>	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
Aug. 22	60	33	55.0%	3	5.0%	0	0.0%	0	0.0%
Aug. 23	98	56	57.1%	4	4.1%	1	1.0%	0	0.0%
Aug. 24	53	30	56.6%	4	7.5%	1	1.9%	0	0.0%
Aug. 25	134	55	41.0%	7	5.2%	9	6.7%	0	0.0%
Aug. 26	61	35	57.4%	3	4.9%	3	4.9%	0	0.0%
Aug. 27	36	16	44.4%	2	5.6%	3	8.3%	0	0.0%
Aug. 28	71	33	46.5%	4	5.6%	7	9.9%	0	0.0%
Aug. 29	97	38	39.2%	2	2.1%	1	1.0%	2	2.1%
Aug. 30	96	44	45.8%	5	5.2%	8	8.3%	1	1.0%
Aug. 31	169	64	37.9%	6	3.6%	8	4.7%	1	0.6%
Sept. 1	325	133	40.9%	12	3.7%	26	8.0%	15	4.6%
Sept. 2	188	85	45.2%	4	2.1%	14	7.4%	8	4.3%
Sept. 3	49	18	36.7%	0	0.0%	2	4.1%	7	14.3%
Sept. 4	110	38	34.5%	0	0.0%	4	3.6%	16	14.5%
Sept. 5	47	27	57.4%	2	4.3%	0	0.0%	8	17.0%
Sept. 6	58	28	48.3%	4	6.9%	0	0.0%	17	29.3%
Sept. 7	89	42	47.2%	1	1.1%	5	5.6%	19	21.3%
Sept. 8	34	15	44.1%	0	0.0%	0	0.0%	2	5.9%
Sept. 9	13	4	30.8%	0	0.0%	0	0.0%	2	15.4%
Sept. 10	38	15	39.5%	4	10.5%	1	2.6%	1	2.6%
Sept. 11	47	19	40.4%	1	2.1%	3	6.4%	0	0.0%
Sept. 12	34	11	32.4%	0	0.0%	1	2.9%	4	11.8%
Sept. 13	43	16	37.2%	1	2.3%	4	9.3%	2	4.7%
Sept. 14	52	11	21.2%	2	3.8%	0	0.0%	1	1.9%
Sept. 15	30	14	46.7%	6	20.0%	2	6.7%	0	0.0%
Sept. 16	21	10	47.6%	0	0.0%	0	0.0%	1	4.8%
Sept. 17	5	2	40.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 18	1	1	100.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 19	0	0	-	0	-	0	-	0	-
Sept. 20	16	5	31.3%	0	0.0%	1	6.3%	0	0.0%
Total	2,075	898	43.3%	77	3.7%	104	5.0%	107	5.2%

^a Not corrected for sex identification error.

Appendix 4c. Incidence of net, lamprey and hook marks and of *Flexibacter columnaris* lesions among jack sockeye examined at tag application in the Chilko River, 1994.

Date	Number of jacks examined	Net marks		Lamprey marks		Hook marks		<i>F. columnaris</i>	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent
Aug. 22	3	1	33.3%	0	0.0%	0	0.0%	0	0.0%
Aug. 23	2	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Aug. 24	2	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Aug. 25	0	0	-	0	-	0	-	0	-
Aug. 26	0	0	-	0	-	0	-	0	-
Aug. 27	2	1	50.0%	0	0.0%	0	0.0%	0	0.0%
Aug. 28	3	2	66.7%	0	0.0%	0	0.0%	0	0.0%
Aug. 29	3	1	33.3%	0	0.0%	0	0.0%	1	33.3%
Aug. 30	4	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Aug. 31	6	3	50.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 1	7	3	42.9%	0	0.0%	0	0.0%	0	0.0%
Sept. 2	3	0	0.0%	0	0.0%	0	0.0%	1	33.3%
Sept. 3	2	1	50.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 4	3	1	33.3%	0	0.0%	0	0.0%	0	0.0%
Sept. 5	2	1	50.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 6	3	1	33.3%	0	0.0%	0	0.0%	1	33.3%
Sept. 7	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 8	0	0	-	0	-	0	-	0	-
Sept. 9	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 10	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 11	8	2	25.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 12	0	0	-	0	-	0	-	0	-
Sept. 13	2	1	50.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 14	6	1	16.7%	0	0.0%	0	0.0%	0	0.0%
Sept. 15	2	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 16	1	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sept. 17	0	0	-	0	-	0	-	0	-
Sept. 18	0	0	-	0	-	0	-	0	-
Sept. 19	0	0	-	0	-	0	-	0	-
Sept. 20	0	0	-	0	-	0	-	0	-
Total	67	19	28.4%	0	0.0%	0	0.0%	3	4.5%

Appendix 5a. Daily sockeye carcass recoveries, by location, mark status and sex, in the north end of Chilko Lake, 1994. ^a

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
17-Sep	A1	-	2	1	0	329	98	7	331	99	7
20-Sep	A3	-	1	1	0	211	247	5	212	248	5
	A4	-	0	0	0	29	21	0	29	21	0
	B1	-	0	0	0	135	122	0	135	122	0
21-Sep	A1	-	1	0	0	371	147	3	372	147	3
	A2	-	1	2	0	278	237	2	279	239	2
	B1	-	2	1	0	328	148	1	330	149	1
	B2	-	0	0	0	15	11	0	15	11	0
23-Sep	A1	-	0	0	0	15	13	0	15	13	0
24-Sep	A1	-	3	0	0	452	245	4	455	245	4
	A2	-	3	0	0	280	353	7	283	353	7
	A3	-	0	1	1	177	251	1	177	252	2
	A4	-	1	1	0	108	81	1	109	82	1
	B1	-	2	4	1	598	481	4	600	485	5
	B2	-	0	0	0	7	19	0	7	19	0
26-Sep	A1	-	0	2	0	39	45	0	39	47	0
28-Sep	A1	-	3	1	0	522	393	9	525	394	9
	A2	-	0	2	0	374	540	9	374	542	9
	A3	-	0	6	1	281	453	9	281	459	10
	A4	-	1	0	0	71	117	4	72	117	4
	B1	-	0	5	1	495	815	0	495	820	1
	B2	-	0	0	0	6	7	0	6	7	0
30-Sep	A1	-	3	2	0	526	330	2	529	332	2
	A2	-	0	0	1	251	296	1	251	296	2
	A3	-	0	4	0	358	287	8	358	291	8
	A4	-	0	0	0	48	54	0	48	54	0
	B1	-	0	1	0	216	251	0	216	252	0
3-Oct	A1	-	2	0	0	114	165	2	116	165	2
	A2	-	0	0	0	165	204	2	165	204	2
	A3	-	0	1	0	196	313	0	196	314	0
	A4	-	1	0	0	44	92	0	45	92	0
	B1	-	0	3	0	144	104	0	144	107	0
	B2	-	0	0	0	13	45	0	13	45	0
5-Oct	A5	-	0	1	0	191	317	6	191	318	6
7-Oct	A1	-	3	2	0	226	440	1	229	442	1
	A3	-	1	0	0	168	479	4	169	479	4
9-Oct	A1	-	2	1	0	287	214	0	289	215	0
	A2	-	0	1	0	218	366	0	218	367	0
	A3	-	0	0	0	27	47	2	27	47	2
	A4	-	0	1	0	32	65	0	32	66	0
11-Oct	A1	-	0	0	0	58	45	0	58	45	0
	A2	-	0	0	0	23	40	0	23	40	0
	A3	-	0	2	0	24	79	0	24	81	0
	A4	-	0	0	0	8	20	0	8	20	0
	B1	-	1	1	0	75	254	4	76	255	4
15-Oct	A1	-	0	1	0	46	108	0	46	109	0
18-Oct	A1	-	0	0	0	4	7	0	4	7	0
	A2	-	0	0	0	0	2	0	0	2	0
	A3	-	0	0	0	0	0	0	0	0	0
	A4	-	0	0	0	0	0	0	0	0	0

Continued

Appendix 5a. Daily sockeye carcass recoveries, by location, mark status and sex, in the north end of Chilko Lake, 1994 continued. ^a

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
Total	A1	13	19	10	0	2,989	2,250	28	3,008	2,260	28
	A2	8	4	5	1	1,589	2,038	21	1,593	2,043	22
	A3	9	2	15	2	1,442	2,156	29	1,444	2,171	31
	A4	8	3	2	0	340	450	5	343	452	5
	A5	1	0	1	0	191	317	6	191	318	6
	B1	7	5	15	2	1,991	2,175	9	1,996	2,190	11
	B2	4	0	0	0	41	82	0	41	82	0
	Total	50	33	48	5	8,583	9,468	98	8,616	9,516	103

^a. See Figure 2 for location designations.

Appendix 5b. Daily sockeye carcass recoveries, by location, mark status and sex, in the south end of Chilko Lake, 1994. ^a

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
10-Sep	Unk	-	0	1	0	6	4	0	6	5	0
17-Sep	A	-	0	0	0	53	60	0	53	60	0
18-Sep	B	-	0	0	0	6	6	0	6	6	0
	C	-	0	0	0	106	122	13	106	122	13
	D	-	0	0	0	4	7	0	4	7	0
	E	-	0	0	0	2	2	0	2	2	0
	F	-	0	0	0	6	4	0	6	4	0
	G	-	0	0	0	14	13	0	14	13	0
	H	-	0	0	0	4	3	0	4	3	0
	I	-	0	0	0	10	12	0	10	12	0
19-Sep	J	-	0	0	0	64	57	0	64	57	0
26-Sep	B	-	0	0	0	12	20	0	12	20	0
	C	-	1	0	0	22	25	2	23	25	2
	D	-	0	0	0	7	11	2	7	11	2
	E	-	0	0	0	3	6	0	3	6	0
	Unk	-	0	0	0	15	18	3	15	18	3
27-Sep	A	-	0	0	0	18	23	0	18	23	0
	B	-	0	0	0	6	10	0	6	10	0
28-Sep	A	-	0	0	0	18	26	0	18	26	0
	C	-	0	0	0	26	37	0	26	37	0
	G	-	0	0	0	10	12	1	10	12	1
	H	-	0	0	0	2	1	0	2	1	0
	I	-	0	0	0	18	21	2	18	21	2
	J	-	0	0	0	47	50	1	47	50	1
29-Sep	A	-	0	0	0	89	92	4	89	92	4
4-Oct	F	-	0	0	0	0	0	0	0	0	0
	G	-	0	0	0	0	2	0	0	2	0
	H	-	0	0	0	48	74	6	48	74	6
	I	-	0	0	0	4	17	1	4	17	1
5-Oct	A	-	0	0	0	3	4	0	3	4	0
	B	-	0	0	0	0	0	0	0	0	0
6-Oct	B	-	0	0	0	0	0	0	0	0	0
	C	-	0	1	0	21	36	9	21	37	9
	D	-	0	0	0	3	10	0	3	10	0
	E	-	0	0	0	4	6	0	4	6	0
7-Oct	A	-	0	0	0	0	3	0	0	3	0
	C	-	0	0	0	30	48	0	30	48	0
	D	-	0	0	0	0	1	0	0	1	0
	J	-	0	0	0	0	6	0	0	6	0
12-Oct	C	-	0	1	0	23	36	4	23	37	4
Total	A	6	0	0	0	181	208	4	181	208	4
	B	5	0	0	0	24	36	0	24	36	0
	C	6	1	2	0	228	304	28	229	306	28
	D	4	0	0	0	14	29	2	14	29	2
	E	3	0	0	0	9	14	0	9	14	0
	F	2	0	0	0	6	4	0	6	4	0
	G	3	0	0	0	24	27	1	24	27	1
	H	3	0	0	0	54	78	6	54	78	6
	I	3	0	0	0	32	50	3	32	50	3
	J	3	0	0	0	111	113	1	111	113	1
	Unk	2	0	1	0	21	22	3	21	23	3
	Total	40	1	3	0	704	885	48	705	888	48

^a See Figure 2 for location designations.

Appendix 5c. Daily sockeye carcass recoveries, by location, mark status and sex, in the Chilko River, 1994.

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
5-Sep	7	-	0	0	0	15	29	0	15	29	0
9-Sep	1	-	0	0	0	17	19	0	17	19	0
	2	-	0	0	0	10	10	0	10	10	0
	3a	-	0	0	0	14	26	0	14	26	0
	3b	-	0	0	0	7	3	0	7	3	0
	4	-	0	0	0	16	8	0	16	8	0
	5	-	0	0	0	11	18	0	11	18	0
6	-	0	0	0	18	16	0	18	16	0	
11-Sep	1	-	0	0	0	11	1	0	11	1	0
15-Sep	1	-	0	0	0	106	23	0	106	23	0
16-Sep	2	-	1	0	0	153	65	0	154	65	0
	3a	-	0	0	0	91	50	0	91	50	0
	3b	-	0	0	0	153	37	0	153	37	0
	4	-	0	1	0	132	53	0	132	54	0
	5	-	3	2	0	277	82	0	280	84	0
18-Sep	7	-	1	0	1	135	42	1	136	42	2
19-Sep	3a	-	1	0	0	83	48	0	84	48	0
	5	-	3	1	0	411	226	0	414	227	0
	6	-	4	0	0	371	125	1	375	125	1
20-Sep	1	-	2	0	0	323	103	2	325	103	2
	2	-	0	0	0	158	120	0	158	120	0
	3a	-	0	0	0	44	46	0	44	46	0
	3b	-	2	3	0	280	256	0	282	259	0
4	-	2	0	0	303	225	0	305	225	0	
21-Sep	1	-	1	1	1	144	65	1	145	66	2
22-Sep	1	-	1	0	0	237	93	1	238	93	1
	2	-	1	3	0	377	338	1	378	341	1
	3a	-	1	1	0	112	132	0	113	133	0
	3b	-	3	0	0	362	385	2	365	385	2
	4	-	0	0	0	182	139	0	182	139	0
	5	-	5	6	0	553	519	1	558	525	1
23-Sep	6	-	5	3	0	684	559	3	689	562	3
	7	-	2	0	0	199	194	0	201	194	0
24-Sep	1	-	2	0	0	376	119	1	378	119	1
	2	-	6	3	0	227	168	0	233	171	0
	3a	-	3	4	0	284	174	1	287	178	1
	3b	-	0	6	0	254	393	0	254	399	0
4	-	1	1	0	130	114	0	131	115	0	
25-Sep	1	-	3	0	0	268	142	1	271	142	1
	2	-	2	2	0	267	226	1	269	228	1
	3a	-	0	1	0	34	18	0	34	19	0
	4	-	3	1	0	326	246	0	329	247	0
	5	-	7	18	1	1,790	1,892	0	1,797	1,910	1
	6	-	7	6	0	680	758	2	687	764	2
7	-	3	0	0	234	184	1	237	184	1	
26-Sep	3a	-	1	2	0	159	207	0	160	209	0
	3b	-	2	7	0	286	581	0	288	588	0
	4	-	3	2	0	150	271	1	153	273	1
7	-	1	5	0	167	238	0	168	243	0	
27-Sep	1	-	4	3	0	598	263	0	602	266	0
	2	-	3	5	0	326	361	0	329	366	0
	4	-	0	3	0	302	349	0	302	352	0

Continued

Appendix 5c. Daily sockeye carcass recoveries, by location, mark status and sex, in the Chilko River, 1994 continued,

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
28-Sep	3a	-	1	1	0	158	152	0	159	153	0
29-Sep	1	-	4	1	0	374	239	0	378	240	0
	2	-	6	2	0	211	316	0	217	318	0
	3a	-	1	9	0	656	799	0	657	808	0
	3b	-	2	3	0	399	1,028	0	401	1,031	0
	4	-	1	10	0	381	900	2	382	910	2
	5	-	12	33	1	2,024	3,752	4	2,036	3,785	5
30-Sep	5	-	13	8	0	1,086	1,898	1	1,099	1,906	1
1-Oct	3a	-	0	1	0	120	124	0	120	125	0
	6	-	8	11	0	1,612	2,773	1	1,620	2,784	1
	7	-	4	8	0	561	1,027	0	565	1,035	0
2-Oct	1	-	7	2	0	476	408	2	483	410	2
	2	-	1	9	0	268	564	0	269	573	0
	3a	-	5	0	0	173	271	0	178	271	0
	3b	-	1	1	0	39	94	0	40	95	0
	4	-	3	8	0	325	727	2	328	735	2
	5	-	16	25	0	1,829	2,721	10	1,845	2,746	10
3-Oct	3b	-	0	10	0	235	919	0	235	929	0
4-Oct	1	-	0	1	0	259	292	0	259	293	0
	2	-	0	4	0	157	461	0	157	465	0
	3a	-	5	2	0	291	390	0	296	392	0
	3b	-	1	3	0	134	341	0	135	344	0
	4	-	0	2	0	181	474	0	181	476	0
	5	-	8	25	0	1,383	2,409	8	1,391	2,434	8
5-Oct	1	-	1	1	0	119	147	3	120	148	3
	2	-	1	2	0	95	245	1	96	247	1
6-Oct	1	-	1	3	0	89	118	0	90	121	0
	2	-	0	0	0	44	72	0	44	72	0
	3a	-	4	4	0	137	262	0	141	266	0
	3b	-	0	5	0	130	534	0	130	539	0
	4	-	1	2	0	152	480	2	153	482	2
	5	-	12	21	0	704	1,804	6	716	1,825	6
7-Oct	1	-	1	1	0	27	40	0	28	41	0
8-Oct	1	-	0	0	0	150	204	1	150	204	1
	2	-	0	6	0	92	461	1	92	467	1
	3a	-	2	2	0	99	150	0	101	152	0
	3b	-	1	3	0	66	440	0	67	443	0
	4	-	1	4	0	105	311	0	106	315	0
	5	-	8	14	0	1,132	1,633	3	1,140	1,647	3
9-Oct	1	-	0	0	0	30	25	0	30	25	0
	5	-	6	11	0	627	1,020	2	633	1,031	2
10-Oct	1	-	2	5	0	129	249	1	131	254	1
	2	-	1	0	0	64	329	0	65	329	0
	3a	-	1	3	0	102	180	0	103	183	0
	3b	-	1	4	1	36	407	1	37	411	2
	4	-	0	2	0	80	296	0	80	298	0
	5	-	2	3	0	140	356	0	142	359	0
11-Oct	3a	-	0	0	0	15	31	0	15	31	0
12-Oct	3a	-	0	0	0	40	128	0	40	128	0
	3b	-	0	3	0	28	318	0	28	321	0
	4	-	0	3	0	59	242	0	59	245	0
	5	-	0	5	0	238	569	8	238	574	8

Continued

Appendix 5c. Daily sockeye carcass recoveries, by location, mark status and sex, in the Chilko River, 1994 continued,

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
13-Oct	1	-	0	1	0	82	175	0	82	176	0
	2	-	0	4	0	47	345	1	47	349	1
	5	-	3	5	0	431	666	0	434	671	0
14-Oct	1	-	0	0	0	44	117	1	44	117	1
	2	-	0	0	0	11	127	0	11	127	0
	3a	-	0	2	0	37	115	0	37	117	0
	3b	-	0	1	0	19	355	0	19	356	0
15-Oct	4	-	0	2	0	69	177	0	69	179	0
	5	-	3	8	0	340	798	0	343	806	0
16-Oct	1	-	1	1	0	22	34	0	23	35	0
	2	-	0	0	0	5	47	0	5	47	0
	3a	-	0	0	0	15	27	0	15	27	0
	3b	-	0	0	0	17	73	0	17	73	0
	4	-	0	0	0	16	53	0	16	53	0
	5	-	1	1	0	58	178	0	59	179	0
17-Oct	1	-	0	0	0	18	22	0	18	22	0
	2	-	0	0	0	8	37	0	8	37	0
	3a	-	0	0	0	23	64	0	23	64	0
	3b	-	0	0	0	14	71	0	14	71	0
19-Oct	4	-	0	1	0	14	75	0	14	76	0
	5	-	2	1	0	71	212	0	73	213	0
20-Oct	1	-	0	0	0	7	12	0	7	12	0
	2	-	0	0	0	13	29	0	13	29	0
	3b	-	0	0	0	5	17	0	5	17	0
21-Oct	4	-	0	2	0	25	54	0	25	56	0
	1	-	0	1	0	5	10	0	5	11	0
	2	-	0	0	0	2	7	0	2	7	0
22-Oct	3a	-	0	2	0	17	31	0	17	33	0
	3b	-	0	0	0	4	16	0	4	16	0
	1	-	0	0	0	10	16	0	10	16	0
	2	-	0	0	0	4	18	0	4	18	0
Total	3a	-	0	0	0	5	18	0	5	18	0
	3b	-	0	0	0	4	33	0	4	33	0
	4	-	0	0	0	8	23	0	8	23	0
	5	-	0	0	0	20	76	0	20	76	0
	7	-	0	0	0	20	76	0	20	76	0
Total	1	25	30	21	1	3,921	2,936	14	3,951	2,957	15
	2	21	22	40	0	2,539	4,346	5	2,561	4,386	5
	3a	23	25	34	0	2,709	3,443	1	2,734	3,477	1
	3b	20	13	49	1	2,472	6,301	3	2,485	6,350	4
	4	20	15	44	0	2,956	5,217	7	2,971	5,261	7
	5	19	104	187	2	13,125	20,829	43	13,229	21,016	45
	6	5	24	20	0	3,365	4,231	7	3,389	4,251	7
7	6	11	13	1	1,311	1,714	2	1,322	1,727	3	
Total	-	244	408	5	32,398	49,017	82	32,642	49,425	87	

Location codes: 1 - Chilko Lake to the DFO camp; 4 - Bottom of Reach 3b to Canoe Cross;
 2 - DFO camp to above the Blue Pool; 5 - Canoe Cross;
 3a - Blue Pool; 6 - Canoe Cross to Lingfield Creek;
 3b - Blue Pool to 0.9 km downstream; 7 - Lingfield Creek to Henry's Bridge.

Appendix 5d. Daily sockeye carcass recoveries, by location, mark status and sex, in the Chilko River spawning channel, 1994.

Date	Location	Number of surveys	Disk tag present			Untagged			Total		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
30-Aug	Total	-	0	0	0	4	2	0	4	2	0
31-Aug	Total	-	0	0	0	13	11	0	13	11	0
3-Sep	Total	-	0	2	0	68	96	0	68	98	0
5-Sep	Total	-	0	1	0	62	97	0	62	98	0
6-Sep	Total	-	0	1	0	107	167	0	107	168	0
7-Sep	Total	-	0	0	0	48	76	0	48	76	0
12-Sep	Total	-	0	2	0	15	37	1	15	39	1
15-Sep	Total	-	1	0	0	39	93	9	40	93	9
16-Sep	Total	-	0	1	0	22	62	4	22	63	4
17-Sep	Total	-	1	1	0	15	8	0	16	9	0
18-Sep	Total	-	0	1	0	29	25	0	29	26	0
19-Sep	Total	-	0	0	0	32	36	0	32	36	0
20-Sep	Total	-	1	0	0	21	33	1	22	33	1
21-Sep	Total	-	0	0	0	32	29	1	32	29	1
22-Sep	Total	-	0	0	0	29	27	0	29	27	0
23-Sep	Total	-	1	1	0	29	16	0	30	17	0
24-Sep	Total	-	1	0	0	59	51	0	60	51	0
25-Sep	Total	-	0	1	0	46	46	0	46	47	0
26-Sep	Total	-	0	0	0	26	37	0	26	37	0
28-Sep	Total	-	0	0	0	53	81	1	53	81	1
29-Sep	Total	-	0	0	0	17	44	0	17	44	0
30-Sep	Total	-	0	0	0	12	32	0	12	32	0
1-Oct	Total	-	0	0	0	8	22	0	8	22	0
Total	-	23	5	11	0	786	1,128	17	791	1,139	17

Appendix 6. Daily number of sockeye carcasses examined and disk tags recovered, by location and sex, during the re-survey of the Chilko River, 1994.

Date	Location	Number of surveys	Disk tag present			Total examined			Disk tag incidence		
			Male	Female	Jack	Male	Female	Jack	Male	Female	Jack
21-Sep	1	-	0	0	0	95	31	1	0.000	0.000	0.000
	2	-	0	0	0	89	81	0	0.000	0.000	-
	3a	-	0	0	0	49	41	0	0.000	0.000	-
	3b	-	0	0	0	6	7	0	0.000	0.000	-
22-Sep	1	-	0	0	0	455	125	0	0.000	0.000	-
	2	-	0	0	0	233	180	0	0.000	0.000	-
	3b	-	0	0	0	161	197	0	0.000	0.000	-
23-Sep	4	-	1	0	0	339	248	1	0.003	0.000	0.000
27-Sep	3a	-	0	1	0	605	513	2	0.000	0.002	0.000
	4	-	0	0	0	155	165	0	0.000	0.000	-
30-Sep	5	-	0	2	0	826	1,304	7	0.000	0.002	0.000
1-Oct	4	-	1	0	0	343	333	2	0.003	0.000	0.000
	6	-	1	0	0	1,110	2,230	0	0.001	0.000	-
5-Oct	1	-	0	1	0	322	442	2	0.000	0.002	0.000
	2	-	0	0	0	143	389	0	0.000	0.000	-
	3a	-	0	0	0	277	697	0	0.000	0.000	-
8-Oct	5	-	1	2	0	997	2,020	0	0.001	0.001	-
10-Oct	1	-	1	1	0	532	759	0	0.002	0.001	-
	2	-	0	0	0	86	175	1	0.000	0.000	0.000
	3a	-	0	0	0	267	414	1	0.000	0.000	0.000
15-Oct	A1	-	0	0	0	752	1,380	3	0.000	0.000	0.000
19-Oct	5	-	1	2	0	674	968	3	0.001	0.002	0.000
Total	1	4	1	2	0	1,404	1,357	3	0.001	0.001	0.000
	2	4	0	0	0	551	825	1	0.000	0.000	0.000
	3a	4	0	1	0	1,198	1,665	3	0.000	0.001	0.000
	3b	2	0	0	0	167	204	0	0.000	0.000	-
	4	3	2	0	0	837	746	3	0.002	0.000	0.000
	5	3	2	6	0	2,497	4,292	10	0.001	0.001	0.000
	6	1	1	0	0	1,110	2,230	0	0.001	0.000	-
	A1	1	0	0	0	752	1,380	3	0.000	0.000	0.000
Total	-	-	6	9	0	8,516	12,699	23	0.001	0.001	0.000

Appendix 7. Fecundity sampling results and analytic details for Chilko River system sockeye salmon captured at Lingfield Creek, 1994.

Sample number	Age	Standard length (cm)	Skein weight (g)	Skein sub-sample		Estimated fecundity	Actual fecundity	Misc. eggs	Adjusted fecundity
				Weight (g)	Egg count				
1	4 ₂	52.0	221.1	118.6	1,259	2,347	2,324	0	2,324
2	4 ₂	55.2	270.7	121.4	1,643	3,664		0	3,664
3	4 ₂	51.6	171.6	101.6	1,295	2,187		12	2,199
4	4 ₂	52.3	148.4	101.5	1,521	2,224		8	2,232
5	4 ₂	53.1	216.8	114.4	1,197	2,268		3	2,271
6	4 ₂	51.5	203.3	107.8	1,293	2,438	2,502	0	2,502
7	4 ₂	53.0	216.8	115.6	1,199	2,249		1	2,250
8	4 ₂	54.3	199.2	102.5	1,543	2,999		3	3,002
9	4 ₂	51.0	181.0	103.1	1,521	2,670		0	2,670
11	4 ₂	49.5	197.6	126.6	1,643	2,564	2,558	0	2,558
12	4 ₂	49.2	179.5	101.4	1,284	2,273		6	2,279
13	4 ₂	53.1	209.1	112.6	1,227	2,279		1	2,280
14	4 ₂	53.0	281.2	124.1	1,315	2,980		2	2,982
15	4 ₂	53.4	278.5	115.1	1,238	2,996		0	2,996
16	4 ₂	53.7	205.1	110.5	1,477	2,741	2,787	12	2,799
17	4 ₂	51.1	205.4	105.6	1,373	2,671		18	2,689
18	4 ₂	53.6	201.5	105.8	1,435	2,733		10	2,743
19	4 ₂	49.3	179.5	103.5	1,215	2,107		12	2,119
20	4 ₂	51.1	213.6	105.0	1,434	2,917		10	2,927
21	4 ₂	53.3	167.3	108.1	1,843	2,852	2,890	13	2,903
22	4 ₂	50.4	196.0	105.4	1,259	2,341		10	2,351
23	4 ₂	55.9	171.7	102.4	1,670	2,800		10	2,810
24	4 ₂	52.2	205.8	103.5	1,327	2,639		10	2,649
25	4 ₂	55.1	209.1	105.3	1,135	2,254		10	2,264
26	4 ₂	52.1	216.1	130.3	1,443	2,393	2,411	0	2,411
27	4 ₂	55.5	198.2	101.8	1,351	2,630		0	2,630
28	4 ₂	49.2	180.2	101.6	1,175	2,084		0	2,084
29	4 ₂	51.5	195.1	102.1	1,500	2,866		0	2,866
30	4 ₂	49.9	212.3	110.0	1,223	2,360		1	2,361
31	4 ₂	49.2	206.8	133.8	1,455	2,249	2,265	0	2,265
32	4 ₂	53.2	213.5	111.7	1,458	2,787		0	2,787
33	4 ₂	55.1	187.0	101.6	1,323	2,435		0	2,435
34	4 ₂	52.4	182.2	101.7	1,514	2,712		0	2,712
36	4 ₂	50.8	161.0	114.4	1,906	2,682	2,642	0	2,642
37	4 ₂	53.2	151.5	101.4	1,730	2,585		0	2,585
38	4 ₂	53.7	207.4	111.6	1,481	2,752		0	2,752
39	4 ₂	54.2	236.8	115.4	1,523	3,125		0	3,125
40	4 ₂	50.8	186.7	115.9	1,524	2,455	2,437	0	2,437
41	4 ₂	54.3	178.7	109.1	1,438	2,355		0	2,355
42	4 ₂	48.4	170.6	101.8	1,332	2,232		0	2,232
43	4 ₂	50.7	204.5	107.8	1,425	2,703		0	2,703
44	4 ₂	52.0	203.4	105.2	1,359	2,628		3	2,631
45	4 ₂	56.9	274.4	121.7	1,530	3,450		0	3,450
46	4 ₂	53.7	233.4	117.8	1,493	2,958	2,948	0	2,948
47	4 ₂	52.0	167.6	102.6	1,513	2,472		0	2,472
48	4 ₂	52.4	236.5	115.0	1,034	2,126		0	2,126
49	4 ₂	53.8	229.3	111.1	1,569	3,238		0	3,238
50	4 ₂	53.0	215.0	116.0	1,484	2,751		0	2,751
10	5 ₂	55.1	238.4	118.7	1,411	2,834		0	2,834
35	5 ₂	54.9	246.0	120.0	1,423	2,917		0	2,917
Mean	4 ₂	52.4	203.7	110.1	1,419	2,609	2,576	3	2,614
	5 ₂	55.0	242.2	119.4	1,417	2,876	-	0	2,876

Appendix 8a. Proportion at age and mean length (Standard and POH) at age, by location, sex and sample period, from the adult sample of sockeye carcasses recovered on the Chilko River system spawning grounds, 1994. ^a

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm)		POH length (cm)	
						Mean	Standard deviation	Mean	Standard deviation
Chilko River	Male	21-Sep to 25-Sep	5 ₂	2	3.0%	59.5	4.95	52.0	4.24
			4 ₂	65	97.0%	53.5	1.84	47.0	1.70
		30-Sep to 04-Oct	Unaged	2	-	55.0	4.24	48.5	3.54
			5 ₂	1	2.5%	64.2	-	56.4	-
		05-Oct to 09-Oct	4 ₂	39	97.5%	54.5	2.43	47.6	2.00
			Unaged	1	-	55.3	-	49.0	-
		Total	5 ₂	7	4.2%	59.6	3.41	52.1	2.97
	4 ₂		159	95.8%	54.0	2.11	47.2	1.81	
	Unaged		4	-	55.0	2.45	48.8	2.06	
	Female	21-Sep to 25-Sep	5 ₂	0	0.0%	-	-	-	-
			4 ₂	43	100.0%	50.5	2.11	45.8	1.93
		30-Sep to 04-Oct	Unaged	0	-	-	-	-	-
			5 ₂	2	2.6%	57.5	0.71	52.0	0.00
		05-Oct to 09-Oct	4 ₂	75	97.4%	51.8	1.73	46.7	1.64
Unaged			0	-	-	-	-	-	
Total		5 ₂	4	2.2%	57.3	0.96	51.8	1.26	
	4 ₂	179	97.8%	51.2	1.89	46.2	1.71		
	Unaged	2	-	49.5	0.71	44.4	0.71		
N. Chilko Lake	Male	21-Sep to 26-Sep	5 ₂	0	0.0%	-	-	-	-
			4 ₂	57	100.0%	53.0	2.36	46.1	1.97
	Female	21-Sep to 26-Sep	Unaged	3	-	55.3	3.21	47.7	2.08
			5 ₂	0	0.0%	-	-	-	-
S. Chilko Lake	Male	18-Sep to 08-Oct	4 ₂	59	100.0%	50.3	1.39	45.7	1.38
			Unaged	1	-	52.8	-	47.6	-
S. Chilko Lake	Male	18-Sep to 08-Oct	5 ₃	6	5.1%	52.3	2.42	46.7	1.63
			5 ₂	1	0.8%	61.2	-	53.2	-
			4 ₃	9	7.6%	43.2	1.64	38.3	1.58
			4 ₂	102	86.4%	50.7	2.10	44.8	1.77
	Female	10-Sep to 05-Oct	Unaged	2	-	49.5	0.71	44.5	0.71
			5 ₃	0	0.0%	-	-	-	-
			5 ₂	0	0.0%	-	-	-	-
			4 ₃	13	11.2%	41.5	1.90	37.6	1.50
Unaged	4 ₂	103	88.8%	49.2	1.75	44.7	1.54		
	Unaged	4	-	48.8	2.36	44.3	1.89		

^a Mean lengths and standard deviations were calculated from length data rounded to the nearest centimeter.

Appendix 8b. Proportion at age and mean length (Standard and POH) at age, by location and sample period, from the jack sample of sockeye carcasses recovered on the Chilko River system spawning grounds, 1994. ^a

Location	Sex	Sampling Period	Age	Sample size	Percent	Standard length (cm)		POH length (cm)	
						Mean	Standard deviation	Mean	Standard deviation
Chilko River	Jack	Study period	4 ₂	2	4.1%	46.0	1.41	41.5	2.12
			4 ₃	5	10.2%	41.8	3.49	36.4	2.61
			3 ₂	42	85.7%	40.9	2.32	35.6	1.99
			Unaged	7	-	42.6	1.90	36.9	1.57
N. Chilko Lake	Jack	Study period	4 ₂	2	3.4%	47.0	1.41	43.0	1.41
			4 ₃	8	13.6%	40.6	2.67	35.8	2.05
			3 ₂	49	83.1%	39.8	1.86	35.0	1.58
			Unaged	7	-	42.4	3.78	38.0	4.28
S. Chilko Lake	Jack	Study period	4 ₂	0	0.0%	-	-	-	-
			4 ₃	54	90.0%	40.1	1.91	35.7	1.53
			3 ₂	6	10.0%	39.3	2.25	34.8	1.83
			Unaged	2	-	37.5	3.54	33.5	3.54

^a Mean lengths and standard deviations were calculated from length data rounded to the nearest centimeter.